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Slash Disposal and Forest Management After Clear Cutting in the Douglas-Fir Region

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Pacific Northwest Forest and Range
Experiment Station
Forest Service

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UNITED STATES DEPARTMENT OF AGRICULTURE

WASHINGTON, D. C., JANUARY 1941



January 1941 • Washington, D. C.

UNITED STATES DEPARTMENT OF AGRICULTURE



Slash Disposal and Forest Management After Clear Cutting in the Douglas-Fir Region

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INTRODUCTION

The treatment and protection of logged-off lands in the Douglas-fir region has long been a perplexing and controversial subject. In particular the problem of slash¹ disposal, especially whether or not to burn, when to burn, and how to burn, have been discussed for years in bunkhouses of logging camps, in offices of logging companies, at logging congresses, at conferences of foresters, in legislative committees. Much has been written on this subject, laws have been passed, and efforts to establish custom and practices continue.

In recognition of the need for more basic knowledge as to the long-time effects of slash disposal, a study on this subject was begun

¹ "Slash," as here used, means the limbs, tops, cull logs, broken underbrush, and other debris left on the ground following a logging operation.

by the Pacific Northwest Forest Experiment Station² in 1926. A major part of the study consists in the establishment and periodic examination of sample plots, located immediately after clear-cutting operations on representative areas throughout the Douglas-fir region that had and had not been subjected to slash burning. To supplement the sample-plot findings, cut-over tracts of known history were studied to trace the results of their treatment on fire hazard, reproduction, etc. This circular should be considered as summarizing present knowledge so gained, and not as the last word on this complex subject.

This summary is addressed to the private and public owners whose primary objective is to grow on their cut-over lands another crop of timber of the best quality and largest volume at the least expense. Cut-over areas on the national forests, some of the other public lands, and a few private properties in the Douglas-fir region are being managed with this avowed purpose. It is not addressed to the owners of logged land who have no interest in growing another crop of timber but are willing merely to give the land the slash-disposal treatment and fire protection that the law requires and that will safeguard their nearby investments in logging equipment or timber. Much of the cut-over land of such owners becomes tax delinquent, a "no-man's land," and ultimately its protection becomes a public responsibility.

Though it is very much in the public interest that cut-over lands be properly managed, it is not within the scope of this circular to discuss the complex problems of forest-land policy, of the economics of land classification for highest use, and of the responsibilities of stewardship of the forest owner to the public, or the steps that are being taken and have been proposed to promote the management of privately owned logged-off lands for sustained forest production. This study has been directed to determining the measures of management that should be taken after clear cutting on all land that is or should be dedicated to permanent forest management, in the interest of forest-crop production and of the safety of forest investments, whether the land is privately or publicly owned.

It is evident that slash-disposal practices developed primarily to reduce hazard may be incompatible with good forest management. It is necessary to look beyond the mere temporary reduction of fire danger and determine the effect of slash disposal on the long-time management of forest lands. This circular therefore includes much published and unpublished information on phases of logged-off land management other than reduction of fire hazard, particularly the results of studies³ (8, 10)⁴ made in recent years by the Pacific Northwest Forest and Range Experiment Station concerning the relation between slash disposal and reforestation.

In collaboration with this station, the Office of Forest Pathology of the Bureau of Plant Industry began in 1928 a study of the pathologi-

² The study was begun by Richard E. McArdle and conducted under his immediate direction until he left the station in 1934. Since then it has been under the immediate direction of the junior author with the assistance of William G. Morris. Preliminary assembling of some of the data was done by Geo. H. Schroeder in the summer of 1937.

³ Also, ANDREWS, H. J., and COWLIN, R. W. FOREST RESOURCES OF THE DOUGLAS FIR REGION. Pacific Northwest Forest Expt. Sta., Forest Res. Notes 13, 1934. [Mimeographed.]

ISAAC, L. A. NATURAL REPRODUCTION IN THE DOUGLAS FIR REGION. 1937. [Unpublished report.]

⁴ Italic numbers in parentheses refer to Literature Cited, p. 54.

cal aspects of slash disposal (14) particularly the rate at which logging debris decays. That study has since been continued and an article thereon has been published (3).

The technique of burning slashings is discussed, largely, on the basis of information gained from stimulating talks with loggers and fire-control executives regarding their own experiences, through observation of their practices, and from handbooks on the subject (27, 28).

REGION AND LANDS UNDER CONSIDERATION

The present discussion is confined to the Douglas-fir region, the territory extending from coast line to timber line on the Cascade Range and from northern Washington to southern Oregon. It is concerned primarily with the care of land from which mature stands of commercial quality have been removed for sawlogs. Slash disposal following the cutting of young stands such as are sometimes exploited for poles, ties, or fuel is a different problem. Unless otherwise stated, the discussion applies to logged areas previously occupied by saw-timber stands that were mature or nearly mature, i. e., stands in which most of the trees were 20 inches or more in diameter.

Though the character of the forests varies very noticeably from section to section, for purposes of discussion the region will be broken down into only two zones, namely, the spruce-hemlock zone or "fog belt," following the coast, with extensions up the principal rivers, in a strip 25 miles or so wide at the north and tapering off narrowly in southwestern Oregon; and the Douglas-fir zone proper, including the rest of the region as far as lumbering extends upward on the mountains, but not the upper-slope forests of balsam firs, mountain hemlock, etc., now rarely exploited. In the spruce-hemlock zone the precipitation is heavy and the humidity holds high through much of the summer, and Sitka spruce and western hemlock dominate the forests. In the second zone Douglas-fir usually composes 60 to 100 percent of the stands, the proportion increasing from north to south with the diminution of moisture. The most common associates are western hemlock, western redcedar, grand fir, Pacific silver fir, Port Orford white-cedar (in southwestern Oregon only), and noble fir (on the upper slopes). Occasional associates are red alder, bigleaf maple, and other hardwoods. In some small parts of this so-called Douglas-fir zone, hemlock or "cedar" predominates.

TABLE 1.—Area of different forest type classes in the Douglas-fir region, by ownership¹

Forest type class	Private	National forest	Other	Total
	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>1,000 acres</i>	<i>1,000 acres</i>
Saw-timber stands, trees mostly over 20 inches in diameter.....	5, 836	4, 346	2, 190	12, 372
Second growth, from sapling size to 20 inches in diameter.....	4, 246	1, 245	1, 006	6, 497
Nonrestocked old cut-overs.....	576	6	84	666
Recent cut-overs, clear-cut since 1920.....	1, 824	54	282	2, 160
Other types (high-mountain types, woodlands, hardwoods, old burns, etc.).....	2, 171	3, 851	1, 285	7, 307
Total.....	14, 653	9, 502	4, 847	29, 002

¹ Forest-survey data as of 1933-34.

Table 1 shows how the 29 million acres of forest lands in the Douglas-fir region is distributed among certain major type and ownership classes. Less than 10 percent of the area of saw-timber stands and a little more than 10 percent of the area of second-growth stands are in the spruce-hemlock forest of the fog belt; the remainder is in the Douglas-fir zone.

LOGGING METHODS

Clear-cutting, as used in this circular, defines a type of logging which removes or knocks down all or practically all of the trees on the land cut over. This term, like the term "cut-over," also designates the results of such logging.

The most common, and until recent years the almost universal, method of logging in the Douglas-fir region is with donkey engine and cable. The machines are powered with either steam, gas, or electricity, and the rigging is either high-lead, slack-line, or tight-line. Regardless of type of machine or rigging, this donkey-engine-cable method of logging almost always results in approximately clear-cutting. All usable trees are felled, to get maximum volume production per acre, and most of the smaller trees are knocked down in the felling of the big trees or are later laid low by the logging lines or by wind. Only occasionally are a few nonmerchantable trees of saw-timber size left standing, in clumps or singly.

In the last few years, to an increasing extent, crawler tractors have been used in this region to haul logs from stump to landing. This equipment may be used in connection with clear-cutting but more often in cutting and removing only the trees of highest merchantability and leaving a considerable part of the stand uncut. This is called partial cutting or selective logging, not to be confused, of course, with selective timber management. Such a method of cutting very much complicates the problem of slash disposal and protection against fire. If no burning is done the hazard is great; if the slash is burned the fire is almost certain to kill the remaining trees, destroying their present or future value, and converting them into snags that will make fire control more difficult.

Tractor logging and the concomitant partial cutting are undoubtedly on the increase, but clear-cutting with donkey engines or some other type of logging equipment is likely to be practiced on a large scale for some time to come. Of the 125,000 to 175,000 acres cut over in this region annually, probably 90 percent would be classed as clear cut. The problem of protecting and managing clear-cut lands will continue for some time to be a large and live issue.

This circular does not deal with conditions following partial or selective cutting. Until more experience has been gained, management of lands so cut must be based largely on adaptation of principles and procedures used on clear-cut areas, tempered by judgment to fit each case.

EXTENT, CHARACTER, AND CONDITION OF CUT-OVER LANDS

The magnitude of the problem of cut-over land management in this region is evident from the greatest area of such lands, their

present unsatisfactory condition, and the very considerable area being added each year by logging.

About 7 million acres, or nearly a fifth of the total land area of the Douglas-fir region has been cut over up to the present time. Some of this has been cleared for agricultural use, some logged 20 or more years ago has reforested naturally and now carries a stand of young trees of various sizes and degrees of stocking, some has been scourged by fire and remains substantially barren of useful growth, some has not yet had time to demonstrate whether it will reforest or not. During the period from 1920 to 1933 somewhat more than 2 million acres was logged.⁵ At this rate, the total for the 20 years including 1939 should reach nearly 3 million acres. In addition, 666,000 acres of older logged-off lands are not reforesting. There were thus in 1938 more than 3½ million acres of recently logged land and older nonreforesting cut-overs, presenting difficult problems of protection against fire and of land management. Each year 125,000 to 175,000 acres of fresh slashings aggravates these problems.

The vast majority of the recently logged lands and of the lands yet to be logged in this region are primarily suitable for timber production. Only a relatively small part of the acreage yet uncleared is better qualified by climate, topography, and soil for agricultural use, or suitable after logging for permanent use as stump pastures for grazing.

That past practices in dealing with clear-cut land are faulty is evidenced by the great acreage that is not reforesting satisfactorily. Strip surveys made by the Forest Survey staff on representative cut-over areas 10 years after logging recorded only 12 percent as well-stocked and 17 percent medium-stocked, but 29 percent poorly stocked and 42 percent nonstocked, indicating unsatisfactory stocking on 71 percent of the total area. This situation, due largely to repeated fires, is particularly deplorable in that much of this great nonreforesting, idle acreage is of good forest soil in a region favored by climate, where timber production might be as rapid as almost anywhere else in the country.

FIRE DANGER ON SLASH AREAS

QUANTITY AND CHARACTER OF FUELS LEFT BY LOGGING

The ordinary clear-cutting operation in the Douglas-fir region leaves behind it an inordinate quantity of debris. Probably in no other forest region in the Temperate Zone, unless it be the redwood region, is there such a mass of cull logs, limbs, tops, smashed logs, rotten wood, and broken-down underbrush littering the ground. Not only is the quantity of slash in the Douglas-fir region enormous, but much of it is resinous and highly inflammable. The needles of Douglas fir, which persist for some time on the twigs, make a very flashy fuel, more hazardous than the less resinous and earlier-shed needles of the spruce and hemlock of the fog belt. The debris from the trees that are felled plus the burnable material already on the land

⁵ ANDREWS, H. J., and COWLIN, R. W. FOREST RESOURCES OF THE DOUGLAS FIR REGION. U. S. Dept. Agr. Misc. Pub. [In press.]

create a very severe fire hazard during certain times of the year. McArdle in the early stages of this study evolved nine classifications for this material: Coarse debris, fine slash, ground cover, underbrush, snags, standing green trees, stumps, rotten logs, reproduction.

Coarse debris includes the larger pieces of waste wood, i.e., pieces more than 3 inches in diameter and 3 feet long. The material of this class on 22 study plots was found to average 62 cords per acre. On individual plots it ranged from 17 to 137 cords. The arrangement of this coarse material was variable; on some plots most of it lay on the ground, on others at least half of it was cross-piled in some fashion. Arrangement has a considerable bearing on the amount of this material that will be consumed in a burning operation, on its rate of deterioration, and on the difficulty of fire fighting.

A contributing cause of the enormous amount of large-size debris left by the usual logging operation is the low standard of utilization prevailing in this region. Low-grade logs are a glut on the market; short chunks, knotty tops, shattered logs, and logs with any considerable amount of defect cannot ordinarily be taken out of the woods at a profit, and so remain to contribute to the fire hazard. Because there is commonly a good deal of rot and other defect, much coarse material would inevitably be left on the ground even were utilization standards higher.

Fine slash includes the needles, twigs, small limbs, splinters, and other dead woody material not classed as coarse debris. Measurements of this material on six small plots indicate that it might amount to 37 to 114 cords per acre, averaging 64 cords. This most dangerous of the fuels on logged-off land is usually thoroughly distributed over the ground, with some concentration about landings, in canyons, and elsewhere where the logging has dragged it.

It should be realized that the greatest element in the fire hazard is not the coarse but rather the fine materials. The coarse materials increase intensity and duration of the heat and obstruct control of the fire; the fine materials make for high ignitibility and rapid spread. Hence, were closer utilization practiced, as it undoubtedly will be in the future, the menace of fire would not be proportionally lessened unless the flashy fuels were likewise lessened.

Ground cover includes the herbaceous plants and the shrubby plants less than 5 feet high. On freshly logged land these consist principally of species present in the virgin forest, such as swordfern, Oregon-grape, and salal. Very soon changes take place in the species composition, even if there is no burning, as will be discussed later. Some of these ground-cover species which predominate after logging are dangerous fuels both when dead and when green; others are actually fire retardants at certain seasons. The composition and volume of the ground cover is therefore a consideration in the management and protection of logged-off land. It appears that immediately after logging about 25 percent of the surface is covered by plants classed as ground cover and that this area increases to nearly 100 percent in a few years.

Underbrush is the shrubby vegetation over 5 feet high present in the virgin forest. Practically all the underbrush is broken down by logging and so adds to the fuel; however, new sprouts appear which shade the fuels beneath them sufficiently to increase their moisture



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FIGURE 1.—Snags should be felled at the time of logging, for they make a fire difficult of control and are a menace to reforestation.

content and retard the spread of fire. The amount of underbrush, like that of ground cover, varies greatly from one area to another and tends to increase with time.

Snags or dead trees that remain standing after logging is concluded are a most serious menace, since they may spread firebrands far and wide. (Fig. 1.) There are usually several such dead trees per acre in the virgin wood. Some of these are knocked down in the felling operation, others by the lines in donkey logging, and it is now the practice to cut most of the remainder during the felling of the green timber or immediately after logging. It is therefore difficult to

estimate the average number that remain on clear-cut lands. Surveys made some years ago indicated that on the region's cut-over lands as a whole there were 3.8 snags per acre. Snags are decidedly a factor to be reckoned with in protecting logged-off land.

Standing green trees on clear-cut areas are potential sources of seed, and therefore desirable. If killed by fire, however, they become snags. Therefore, there is no advantage in leaving green trees unless they can survive the slash burn. They are also highly subject to wind-throw and if thrown add to the fuels on the ground.

Stumps as they rot afford dangerous lodgment for sparks. Pitchy stumps and roots make fires that are difficult to put out.

Rotten logs, not originating from trees that are felled, are present on the floor of most old forests of this region. When the forest canopy is removed they dry out, at least on the surface, into ready tinder for sparks. Under certain conditions they hold fire persistently.

If advance reproduction is present in the virgin forest, some of it is made into tinder by logging and some survives. Neither living advance nor subsequent reproduction can be considered to add much dangerous fuel to the already enormous amounts of slash and to the annually accumulating herbaceous growth. Rather, the reproduction, as it develops and shades the ground, is an aid to forest protection.

OTHER FACTORS CONTRIBUTING TO FIRE DANGER

The enormous amount of highly combustible debris would not present such a serious problem in fire protection if it quickly disintegrated, if slopes were not so steep, if the climate were continuously moist, or if there were few agencies to start fires. But such is not the case. Here in the Northwest fires run fast on steep slopes covered with debris; the slash remains a very inflammable fuel for several years after logging; the climate is extremely dry and conducive to fires during a material part of the year; and the agencies that might start a fire are many.

CLIMATE

Though the days each season when fires will run dangerously in dense virgin or second-growth woods are rather few, debris on logged-off lands is likely to be in a highly combustible condition practically all of July and August (when rains are very infrequent), off and on between rains in April, May, June, September, and October, and even occasionally in February, March, and November.

TOPOGRAPHY

Since fires spread more rapidly and are more difficult to control on steep slopes than on level or gently rolling ground, topography is an important factor to be considered in studying the management of cut-overs. The valleys and rolling hills of the region were logged first because they were most accessible and cheapest to log. Much of the remaining timber is on rugged topography; hence the cut-over lands tend to be more rugged each year.

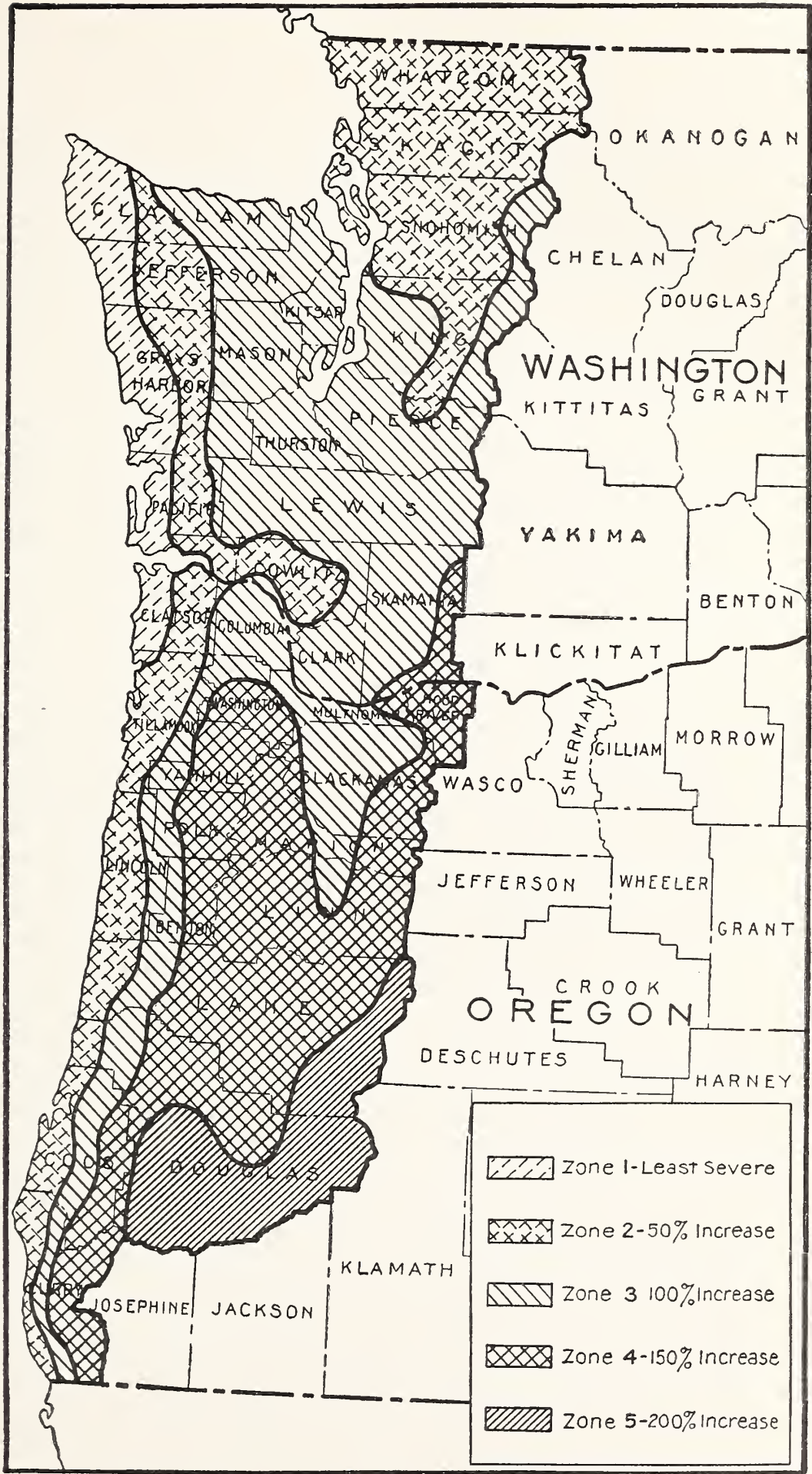


FIGURE 2.—Zones of climate in the Douglas-fir region rated according to the severity of the forest fire hazard.

Variations in these conditions must be recognized, however. These variations are chiefly geographic but are also caused by daily weather conditions and diurnal changes in temperature and humidity.

In the fog belt along the coast the humidities are higher, the droughts shorter, and the number of fire days fewer and less severe than in the interior valleys, in southern Oregon, and on the Cascade Range. Likewise, the northern part of the region experiences more rain and fewer high temperatures and low humidities than the southern part. In rating climatic hazard as a factor in his forest insurance study, Shepard (24) zoned the region (fig. 2) according to five factors—seasonal precipitation, mean drought period, maximum drought period, number of days below 35-percent relative humidity, and minimum relative humidity. This rating of the elements of fire weather indicates that the summer climatic conditions are three times as severe in zone 5 as in zone 1. In addition, even in the driest part of the summer, the hazard varies from day to day with changes in the atmospheric humidity and the wind; and there is also some diurnal variation, for at night the relative humidity is high and the finer fuels absorb a considerable percent of moisture. These seasonal and diurnal fluctuations in the fire hazard are important considerations in conducting slash burning and in protecting logged areas in any protection zone.

CAUSATIVE AGENCIES

The majority of the fires on cut-over lands are man-caused. The public flocks onto this land, made accessible by roads, to pick blackberries, to fish, or to hunt, and the careless minority cause many fires. There is always a chance both before and after slash burning that a nearby logging operation may ignite the very inflammable fuels by a spark from a logging engine, brake shoe, blasting, lunch fire, smoking workmen, cable friction, the exhaust of a gasoline engine, or some other source. Logging operations cause a small percent of all fires, but account for a much larger percent of the total damage and fire-fighting cost. For example, a study of the fires on private lands in Clatsop, Columbia, Washington, Tillamook, Multnomah, Yamhill, Clackamas, Lincoln, Polk, Marion, Benton, Linn, Lane, Douglas, and Coos Counties in Oregon for the period of 1921–32, inclusive, revealed that, although logging fires were only 11 percent of the total number, they accounted for 37 percent of the damage and 35 percent of the fire-fighting cost. This same study attributed the remainder of the total number of fires in these counties to causes as follows: Lightning, 3 percent; incendiary, 31 percent; recreation, 28 percent; land clearing, 15 percent; railroad, 2 percent; and miscellaneous and unknown, 10 percent. Throughout the region the stump rancher is a flagrant cause of fire on logged land surrounding his clearing. Frequently there is actual incendiarism. In the Coast Range and in western Washington and northwestern Oregon valleys, lightning is not a serious factor in starting fires, but in the remainder of the region this cause is important.

CONFLAGRATION HAZARD

If large areas of unburned slash unite to form one continuous mass of highly inflammable fuel a very serious conflagration hazard may

result. Given other favorable conditions, experience has taught that a fire which has extensive, continuous masses of favorable fuels to feed upon may gain such momentum and spread to such proportions that control is well-nigh impossible. Local fire history records several major conflagrations of 50,000 acres or more starting in cut-overs, the most recent being the Tillamook fire of 245,000 acres in 1933 and the Saddle Mountain fire of 180,000 acres in 1939. This possibility has had a major influence upon slash-disposal laws and practices of the region, many of which are aimed to prevent the accumulation of extended and continuous areas of highly inflammable fuel.

SLASH-DISPOSAL LAWS AND PRACTICES

For many years the laws of both Oregon and Washington have recognized an unburned slashing to be a menace to life and property and have placed on the owner responsibility for fires originating therein. Indeed, reduction of the fire hazard is the principal consideration at present (1, 12); the effect of slash disposal on reforestation has been a minor consideration. As a result of these strict laws, it has been the general practice to broadcast-burn slashings. Oregon's present law requires that "every person creating a fire hazard shall, unless relieved by the State Forester, each year remove such hazard by burning his annual slashing." It also requires the current felling of all snags over 25 feet high and 16 inches in diameter in the Douglas-fir region (exclusive of Jackson and Josephine Counties). Washington's law does not specifically require that slash be burned unless it is declared a hazard and ordered burned by the supervisor of forestry, who is directed in the following words to measure the advantages and disadvantages of slash burning:

Whenever the State supervisor of forestry shall determine that the burning of any area will result in the destruction of seed trees and second growth and will be detrimental to the growth of a new forest crop, and that burning such area will create a greater fire hazard than already exists, he may issue a certificate of clearance for such areas.

He may also require the felling of snags on slash areas "within the area to be burned which in his judgment constitute a menace or are likely to further the spread of fire therefrom." It has been the general practice of the State foresters of both States to require the firing, under proper precautions, of nearly all clear-cut slash as soon after logging as possible.

In both States the landowner carries responsibility for suppression costs and property damage resulting from any fire originating in unburned slash, unless relieved of such responsibility by the State forester. When release has been obtained from the State forester, whether or not slash is burned, fire suppression is taken care of by the State, or a protective association, except where the landowner is definitely responsible for the origin of the fire.

The rules of forest practice (28) adopted by the West Coast logging industries under the N. I. R. A. code, and followed voluntarily by many operators since the code became inoperative include this provision under the heading "Fire Protection During and Immediately Following Logging":

Where slashings resulting from logging are to be broadcast burned, plans shall be prepared in advance of burning, showing areas to be burned, methods and precautionary measures contemplated. Areas of second growth, groups of trees left for seed supply, and stands of timber adjacent to slash, shall all be given adequate special protection to prevent damage, where necessary, by construction of fire trails, backfiring before the main slash is fired, or other special measures required. When greater damage would result from broadcast burning of slash than already exists, from both fire-protection and silvicultural viewpoints, such areas shall be relieved from broadcast burning provided such relief shall be approved by the State Forester in writing.

Most operators in the Douglas-fir type proper are sympathetic with the requirements of the State laws and want to burn their slashings promptly. Some, however, are dilatory in burning and once in a while allow 2 or 3 years' slash to accumulate. In the fog belt and the northern Cascade Range many operators are not in favor of burning, believing that in their climate slashings can be kept free of fire and that the burning is likely to do more harm than good—a question that will be discussed more fully below. In the spruce-hemlock type the State foresters more frequently relieve operators from burning than in the Douglas-fir type proper.

The usual season for slash burning is the fall, although some is done in the spring. The logger or landowner burning in the fall prefers to do so when the fire will be intense and do a good clean-up job, and so does not wait until the slash has been wetted by much rain. Some areas, unfortunately, accidentally catch fire in mid-summer before the proper slash-burning season arrives, often with considerable damage to adjoining logging operations, virgin timber, and reforestation cut-overs.

Broadcast burning is the universal method. No other method is physically and economically possible, because of the enormous, continuous mass of fuels. The typical slashing fire, feeding on thousands of cords of resinous fuel, becomes terrifically hot, throws sparks far and wide, and is very difficult to control. When it escapes to adjoining land, it may run for a considerable distance into green timber and kill commercial trees before it can be stopped or loses its momentum. Sometimes it spreads to land already once slash-burned and by killing the oncoming reproduction postpones the time when the land will be reclothed with a fire-resistant second-growth stand. Reliable statistics as to the area unintentionally reburned by intentional slash fires are not available, for until recently such areas have customarily not been included in the statistics of accidental and fought forest fires except on the national forests. The area is thought to be very considerable in the aggregate and to constitute a material factor in the management of logged lands for continuous production. In recent years, however, slash-disposal operations have been conducted with more care, more promptly, and with less damage to surrounding areas.

RELATION OF SLASH DISPOSAL TO FIRE HAZARD

Since the only practical alternative to broadcast slash burning is to leave slash unburned and give cut-over areas added protection for as long as necessary, it is pertinent to determine the effects on fire hazard of burning or protecting slashings, 1, 5, 10, or more years after logging; to know, for example, for how long broadcast burning

reduces fire hazard; for how long unburned slash remains a high fire hazard; and what factors chiefly constitute the fire hazard on a cut-over area; and how and to what extent can each be controlled.

METHODS OF FIELD STUDY

SELECTION OF STUDY AREAS

In order that these and similar questions might be answered, the field study was planned to afford a contrast between the effects, over a period of several decades, of burning slash and of leaving it unburned. Several factors made it impractical to proceed according to an ideal paired-plot design, carried through 20 years or more. For one thing, burning broadcast is ill-adapted to the requirements of permanent paired-sample-plot maintenance. For another, time was lacking for so deliberate an approach. Instead, such areas as could be found were examined by means of semipermanent plots.

Most of the findings reported here are based upon a study made in 1935 of 42 unburned and 85 burned areas, hereafter called tracts, of known fire and cutting history that had been logged 10 to 20 years previously. These tracts varied mostly from 10 to 40 acres each. They were not marked on the ground, but so recorded that they could be reexamined at any time.

The observations made upon these tracts were supplemented by records obtained from earlier observations running back to 1926. Between 1926 and 1930, 58 burned and unburned plots $\frac{1}{4}$ to 1 acre in size and of known fire and cutting history, were established on recently clear-cut areas in various parts of the Douglas-fir region, and upon these were made observations already referred to of the amount and kind of fine and coarse fuels, and also of the amount and kind of vegetation present. Such of these plots as remained unburned by subsequent fires were reexamined every year or two up to 1930, and again in 1932 and 1935. Other records were available from larger tracts, both burned and unburned, laid out in 1932 and reexamined in 1935. In the course of these studies many additional areas were observed that for one reason or another could not be used formally but nevertheless serve as background material for some of the conclusions based on the recorded data.

The study as a whole sampled the Douglas-fir cut-over areas in a representative manner, covering plots or tracts in Jefferson, Clallam, Mason, Grays Harbor, Skagit, Snohomish, King, Pierce, Lewis, and Skamania Counties in Washington and in Columbia, Clackamas, Tillamook, Marion, Linn, Lane, Lincoln, Douglas, and Coos Counties in Oregon. The age of all the cuttings examined ranged from a few months to 50 years; most of the areas, however, had been cut over since 1900.

MEASURING FIRE HAZARD

A basic problem in the study of the effect of slash burning was the development of an adequate means of measuring or appraising fire hazard locally. The method employed was essentially that used by Hornby.⁶

⁶ HORNBY, L. C. FIRE CONTROL PLANNING IN THE NORTHERN ROCKY MOUNTAIN REGION. N. Rocky Mt. Forest and Range Expt. Sta., Prog. Rpt. No. 1, 179 pp., illus., 1936. [Mimeographed.]

Fire hazard is properly an estimate of how fast fire will spread in forest fuels and how much effort will be required to control it under a standard set of weather conditions. Measuring fire hazard is therefore essentially measuring the kind, quantity, arrangement, and inflammability of fuels. This is expressed in terms of (1) probable rate of spread of fire and (2) the probable effort required to control a fire, called resistance to control. A purely quantitative comparison of fuels is inadequate and misleading; often there is no direct relation between quantity of fuel and total fire hazard. Kind, arrangement, and inflammability of slash on an area with only 500 cubic feet of slash per acre may result in greater hazard than is presented by another area with 1,000 cubic feet per acre.

To make possible a reliable measurement of forest fuels, milacre squares (6.6 by 6.6 feet) were laid out as sample plots, in what has been termed elsewhere (19) the "small-plot method." From 1 to 10 of these plots were located on an acre, largely by chance. So far as practicable, all plots were taken on level or nearly level portions of each tract in order that the results might be comparable. The observer stood at the center of each plot and recorded the kind, quantity, and distribution of all green and dead fuels in each of 6 zones on and above the plot: (1) Crown zone, and (2) secondary crown zone, both 30 feet or more above the ground (and therefore seldom found on any but the older clear-cut lands and in partially cut or uncut stands); (3) 30- to 5-foot, or high-brush, zone; (4) 5- to 1-foot, or low-brush, zone; (5) 1- to 0-foot, or ground-cover, zone; and (6) surface and duff zone. The density of cover in the upper zones 1 to 4 was studied principally because of the influence of shade on the moisture content or inflammability of the fuels underneath. When more precise measurements of the quantity of shade on each plot are desired a photoelectric cell should be used (20). In the 2 lower zones, where most fires spread, the kind, quantity, and arrangement of fuels received special attention.

Observations were made and recorded, also, regarding aspect, soil, and topography. Soils were classified according to their effect on fire control, i. e., effect on resistance to control or on the digging of fire trench. In order to have all plots on the same basis, it was assumed that the snags on all tracts were down. The number, size, and distribution of units of such coarse fuels as limbs, poles, tops, windfalls, cull logs, and chunks were estimated and recorded on each plot, and also the amount of rotten wood. A record was made of the history of the plot, i. e., the dates when it was cut-over, burned over, etc.

In addition to the physical inventory and history the observer made an independent estimate of the probable rate of spread of a fire (of approximately the size of the plot) and the probable resistance to control on each plot under an assumed standard set of burning conditions as, namely, an average bad fire day in August with normal wind. Four classes of rate of spread were recognized—low, moderate, high, and extreme. For convenience in making comparisons these classes are assumed to have the approximate numerical relation one to another of 1, 2, 4, 8, the low rate (1) being considered typical of a virgin old-growth Douglas-fir forest (fig. 3), where the principal fuel is a layer of mossy duff, and the highest rate (8) repre-



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FIGURE 3.—Douglas-fir—hemlock forest before the harvest, with a minimum of underbrush, windfalls, and litter. The fire-hazard rating is LL—low rate of spread and low resistance to control.

sents the fastest spreading fuels in the region. Zero ratings were used when plots fell where there was no fuel for a fire to spread in, as on bare ground or rock. Although each of the rate-of-spread classes has been assigned a numerical index value, these assumed values are not absolute and should not be taken literally. They are probably conservative because recent studies indicate that the rate of spread in the fastest burning fuels is probably considerably more than eight times that in the class of fuels classified as low.

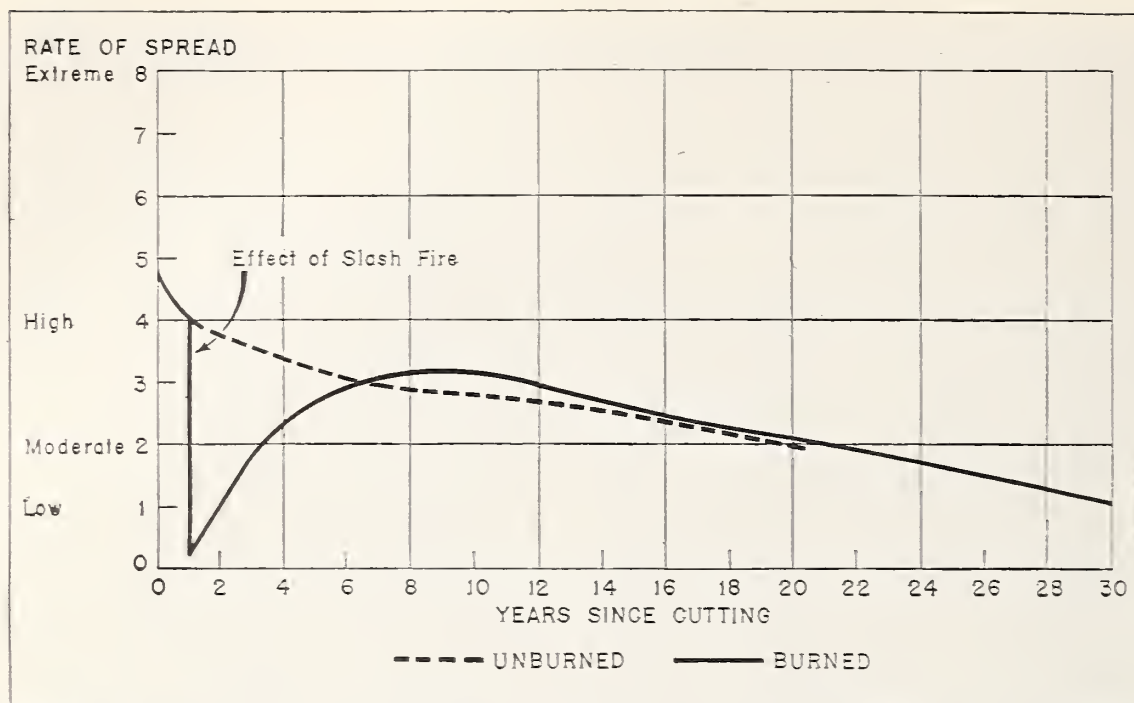


FIGURE 4.—The trend of rate-of-spread ratings of burned and unburned cut-over lands with the passage of time.

Resistance to control, or the amount of hand work by usual methods that would probably be required to corral a fire approximately the size of the plot, was estimated in four similar classes—low, moderate, high, and extreme, having also the numerical values 1, 2, 4, 8. A zero rating was also used. Here low was assumed to approximate conditions in the virgin old-growth Douglas-fir forest of the open type, with little or no undergrowth (fig. 3), where the principal fire-control job consists in digging a trench to mineral soil and where soil and root conditions are favorable to digging. If, for example, the observer estimated that twice as many man-hours would be required to corral a fire on a given plot as on such a low-resistance plot, a moderate rating was indicated.

RATE-OF-SPREAD FACTOR

The pronounced drop in the trend of the rate-of-spread ratings (fig. 4) on the burned areas 1 year after cutting, is not intended to imply that all slash is burned exactly 1 year after cutting, but indicates that, since most slash burning is now done in the autumn, a considerable part of the unburned slash is carried through one fire season on an active logging operation. Since the average slash fire consumes most of the finer fuels, a second fire will not spread or only very slowly, and hence the curve representing burned areas starts practically at zero. In sharp contrast, unburned slash, full of resinous needles and twigs that burn with almost explosive violence, is in its most dangerous condition in the first dry weather after it is cut, when most of the needles are still attached to the branches. Were it not that the powerful high-speed machinery now in common use in logging tends to break up the tops, grind the slash into the ground, and leave many streaks of bare ground where moving logs have cut into the earth, fresh unburned slash would receive a higher rating.



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FIGURE 5.—A, Unburned slash immediately after clear-cutting. B, Same spot 4 months later immediately after the slash fire. The finer fuels have been consumed, the cull logs and chunks have been reduced in size and many of them burned in two; the fire hazard temporarily is low. C, The same spot 2 years after the slash fire is covered with a dense growth of annuals which furnish a flashy fuel and increase the hazard.

It was found that in most cases rate of spread increases rather sharply in the years after a slash fire (fig. 4). One of the principal factors contributing to this result is the herbaceous growth, such as senecio, fireweed, thistles, and grass, that quickly seeds in on most areas. After one growing season the dead stalks make a sufficiently continuous layer of fine fuel to carry a fire (fig. 5). Many fast-spreading fires have been due to this herbaceous growth in the first few years after all fine material in the slash had apparently been consumed down to mineral soil. Bracken and other ferns have a like effect, also lichens and moss. Blackberry vines, covering some burned areas quickly, furnish dead stems and leaves in a year or two. Many kinds of bushes sprout from the roots after a slash fire. In some cases small trees of hemlock and other species, killed by the slash fire, fall in a few years and furnish new fuel. Also there are usually many pieces of coarse fuel that, although charred superficially, dry out and flake up under full exposure to the sun.

Another important source of fuel in the years immediately after a slash fire is flattened masses of rotten wood, remaining from ancient windfalls of fire-killed trees. Some of this material is stirred up by the logging, but part may pass undisturbed through both the logging and the slash fire. When, on full exposure to the sun and wind, it becomes dry, flaky, and loose, it catches sparks easily and thus gives birth to spot fires more readily than almost any other fuel commonly found on such lands. Although this decomposed wood has lost most of its fuel value, fires smolder and creep in it so persistently that it often forms a path by which the fires reach more flashy fuels.

The amount of this rotten wood in old-growth forests, occasionally in a continuous layer several inches thick, varies greatly throughout this region. In general it is most plentiful in damp climax forests of spruce-hemlock, hemlock, and "cedar" that have had no fires for centuries, and least abundant in forests that have had recent surface fires or have come in on burns within comparatively recent times. In general, summer or fall slash fires consume more of this material than spring or early summer fires, since it dries out slowly. It is, however, undeniable that this same rotten wood, as a counterbalance to its high fire hazard, undoubtedly plays an important role in protecting the soil from erosion and in furnishing an environment in which seedlings will thrive.

Rate of spread on individual areas varies widely from the general trend for the region as a whole, shown in figure 4. On some thin, rocky soils a severe fire may burn up all combustible material so completely, and leave the soil in such a sterile condition, that no vegetation will start and rate of spread stays at almost a dead level near zero for decade or longer. Other soils, particularly the deep soils of the fog belt (with climate as an important accessory factor), may support a quantity of vegetation 2 to 5 years after burning that will produce a fuel mass deserving a considerably higher rating than that shown on the graph.

Unburned slash areas present a somewhat different picture in the first years after logging. Whereas on burned areas the fuel from new vegetation of various kinds is the principal factor in building up rate of spread, on unburned areas annuals do not usually come in so thickly and slash is itself the principal fuel for many years.

In time, however, the fire hazard is considerably reduced. First, the needles drop off, and then the winter rains and snow tend to pack it so that many masses are formed which hold dampness. This compacting is possibly the most important factor in reducing probable rate of spread of fire. Any growth of annuals and vines tends to increase the rate of spread by providing additional fine fuel. On the other hand, the shade of sprouts from brush and hardwoods tends to keep fuels more moist. The small-plot data witness to heavier growth of vegetation in the first 10 years in both the 1- to 0-foot and 5- to 1-foot zones on unburned than on burned areas (fig. 6, *A* and *B*). This is particularly noticeable in the fog belt, where brush and vines may almost completely fill the 5- to 1-foot zone in a few years, shading very effectively the slash underneath and reducing rate of spread. The density of the cover, all species of brush and reproduction combined, in the 30- to 5-foot zone (fig. 6, *C*) remains low on both burned and unburned lands until after about the tenth year, and reaches its maximum shortly after 20 years. It is apparent that in this zone shade is generally produced somewhat sooner on unburned areas and slightly more abundantly than on the average burned area.

Childs (3) found that although decay causes a decided reduction in dry weight (and fuel value) of slash, its effect on fire hazard is by no means proportional to this reduction. Other conditions being equal, decayed slash may be as effective in supporting and spreading fire as is similar sound material, and under some conditions it may be even more effective, since, for example, sparks will catch more readily on dry, decayed than on sound wood. Childs (3, p. 959) makes this significant statement:

It must therefore be concluded that decay merely enhances the effect of exposure or shade on the moisture content of slash, and that the gradual reduction of fire hazard on slashings is caused primarily by the development of a dense protective cover of shrubs or reproduction.

Childs also found that hemlock sapwood had on the average about twice as high a moisture content in unburned slash as on burned areas 6 years after logging.

The shade produced by the sprouting brush and hardwoods on unburned areas is a major factor in reducing rate of spread, because of its action in holding the moisture content of all surface fuels to a higher level than on any areas without this shade. Results⁷ of some tests of fuel moisture under various cover conditions on the Wind River Experimental Forest, Wash., (fig. 7) indicate that fuels become drier during the day on unshaded cut-over land than under the shade of brush and much drier than under the shade of saplings or virgin timber. Figure 7 also indicates that the shade from saplings is as effective as the shade of the virgin forest.

Again it should be stated that wide variations may be found in individual cases. On some unburned slash areas probably little decrease, or possibly some slight increase, in rate of spread takes place in the first few years, and on others the decrease is probably much more rapid than that indicated here.

⁷MORRIS, W. G. DIURNAL CHANGES IN FUEL MOISTURE IN THE DOUGLAS FIR FOREST AS AFFECTED BY COVER CONDITIONS. Pacific Northwest Forest and Range Expt. Sta., Forest Res. Notes 23: 11-12. 1937. [Mimeographed.]

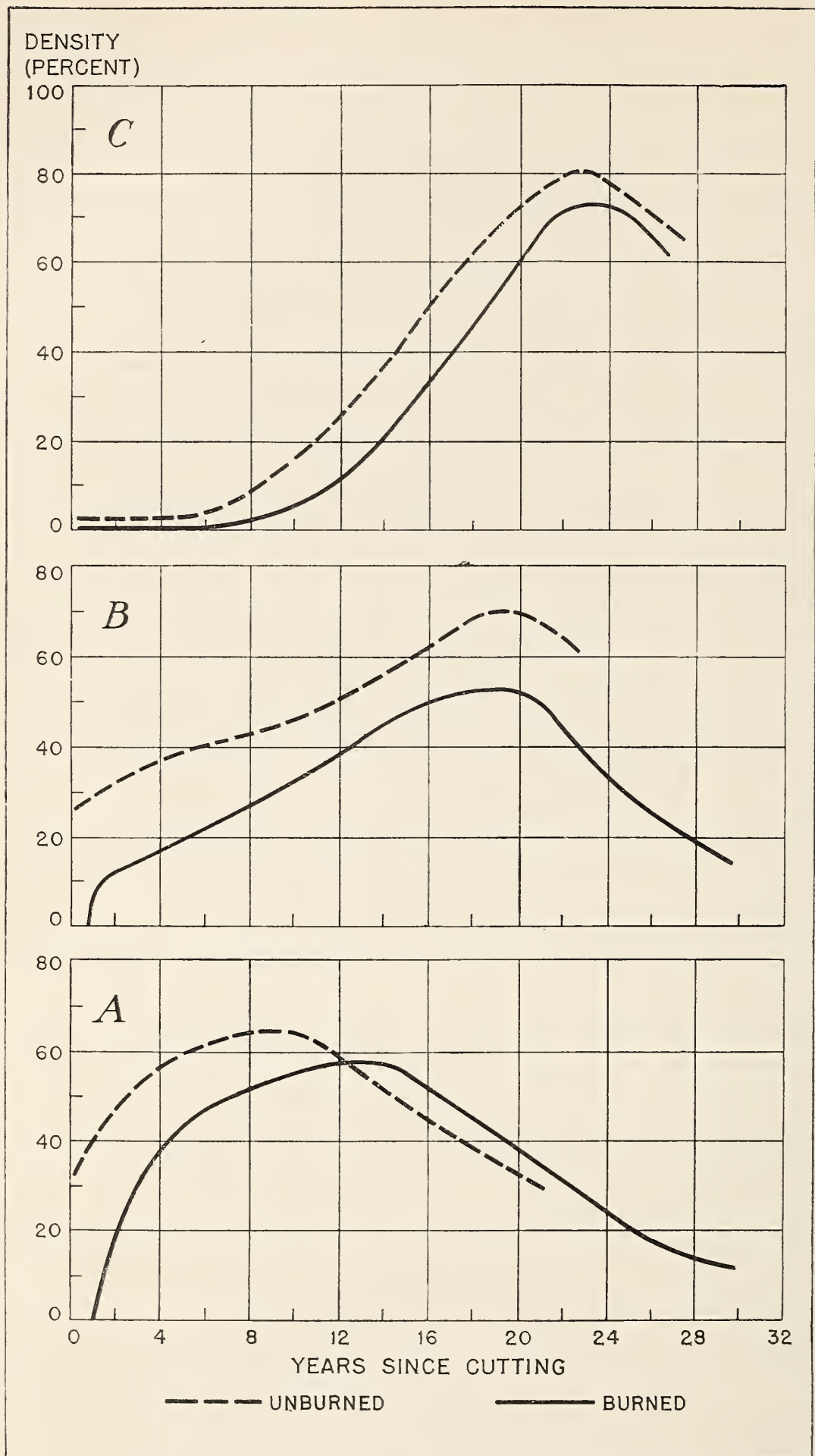


FIGURE 6.—Density of the shade furnished by the green fuels on cut-over land for various years since cutting, expressed in percentage of full shade, (A) in the 1- to 0-foot zone above the ground; (B) in the 5- to 1-foot zone; and (C) in the 30- to 5-foot zone.

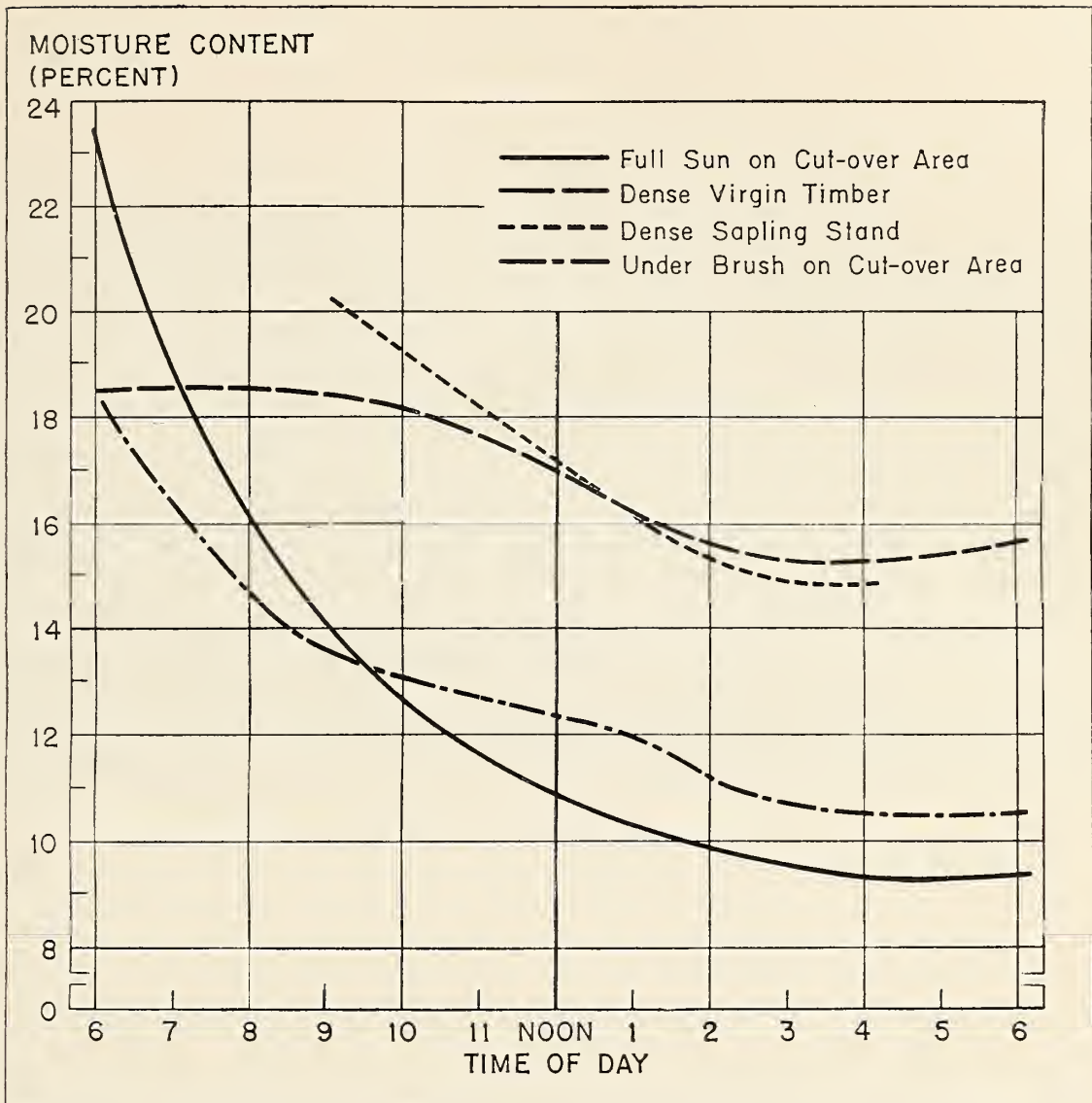


FIGURE 7.—Typical daily change in moisture content of fuel-moisture-indicator sticks exposed under different cover conditions during average bad fire weather.

In the present study it was found that the quantity and distribution of fine dead material, most of which occurs on the surface of the ground or directly above the surface in the 1- to 0-foot zone, were most important in determining the rate-of-spread rating, since a small amount of loose fine material will burn more rapidly than the same or even a larger amount closely packed. This is a fact well known to fire fighters and is important in rating and comparing areas.

Before an estimate of the probable rate of spread was made, the amount and kind of all fine dead material on each plot most likely to determine rate of spread under the assumed weather conditions were estimated and recorded. When these records were later compared with the rate-of-spread ratings it was found that the greater the amount of fine material, the greater the rate-of-spread rating. In addition, the loose type of fine material, such as standing or supported weeds and slash, gave a greater estimated rate of spread than did an equal amount of the packed conifer litter found under dense closed stands of young trees or an equal amount of packed hardwood leaves as found under alder, maple, and brush thickets.

Deserving special mention in this type of fuel are needles and twigs of conifers, bracken, swordfern, limbs, leaves and twigs of brush or hardwood trees, fireweed and other weeds, grass, salal leaves and twigs, and trailing blackberry vines.

The most interesting indication in figure 4 is the very distinct tendency for the rate of spread on a burned area to increase rapidly until it has equaled that on an area of unburned slash of the same age. This is not due to any very marked decrease in the rate in unburned slash. The period required for the equalization will vary widely; in this study it was 6 years, but in other instances the rates of spread may never become equal, or may require 10 or more years to do so.

The effect of a slash fire in reducing rate of spread is thus shown to be very temporary. On most timbered lands in the Douglas-fir region the rate-of-spread rating averages not higher than moderate, or 2 on the rating scale, but cut-overs, within about 6 years after slash-burning, will have an average indicated rating between high and moderate, significantly higher than in green timber. The facts that this rating is based on level, or nearly level, ground with no snags, and that once-burned cut-over lands with steep slope or snags, or both, would have a higher rating, bring out even more sharply the temporary effect of a slash fire in reducing rate of spread.

The field-study data do not show any significant difference between the rate-of-spread ratings of unburned and burned areas after about 6 years. On burned areas there is some slight tendency for the rating to increase for a few years and on the unburned areas there is a consistent, very gradual downward trend. Variations on some individual areas are undoubtedly due partly to soil and climate; others can be traced to effect of fire. In general, the unburned areas carry more fuel, offset by denser vegetation and more shade. The kind of vegetation differs somewhat on the two types of area; 6 to 10 or 12 years after logging, sprouts of brush and hardwoods and straggling conifer survivors—principally hemlock—are usually more prominent on unburned areas, while weeds, vines, and bracken are likely to be more prominent on burned areas. About this time the bark sloughs off the dead hemlock poles; their surface becomes flaky and hence more inflammable. Douglas-fir bark, being thicker, does not disintegrate so rapidly, and hence large Douglas-fir logs do not show much change.

After about 15 years, superficial examination may disclose very few points of contrast between burned and unburned slash areas. Except for the presence of charred surfaces, it is sometimes difficult to tell them apart. Indeed, the data collected by the small-plot method indicate that the rate of spread on cut-over lands after about 15 years depends more on the amount and type of cover than on any discoverable tendency due to slash fire or its absence. From this time forward, shade from reproduction has a profound effect on rate of spread. The direct effect of this shade is to increase the moisture content of fuels considerably above the moisture content of the same fuels in the open (fig. 7); its most important indirect effect is in shading and thus killing some of the herbs, vines, bracken, and brush, thus eventually reducing materially the amount of fuel from these sources. In the end it completely changes the character of the vegetation, result-



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FIGURE 8.—A full cover of young trees is the best antidote for the fire hazard that follows clear cutting. This area was broadcast slash burned following logging about 20 years ago.

ing in a typical forest cover. A considerable proportion of the ground surface is covered, principally by moss, needles, and hardwood leaves.

Study of the rate of spread on cut-over areas indicates that this shading-out process is tremendously important. Any procedure in handling slash areas that will promote rapid formation of a complete forest cover and dense shade of conifers or such hardwoods as alder, bigleaf maple, and willow will do more to reduce the rate-of-spread rating than almost anything else now known. Therefore, it follows that anything which promotes reforestation also promotes reduction of fire hazard.

Imagine two areas logged 20 years ago. On one for some reason there has been no tree reproduction, but instead annual herbs, bracken, vines, and scrubby brush grow rank, with the result that rate of spread is just as high as at any time 5, 10, or 15 years after logging, or higher. On the second, a fully stocked stand of Douglas-fir, hemlock, and "cedar" reproduction came in immediately after logging, producing in 20 years a dense shade and a ground cover principally of needles and moss. (Fig. 8.) The complete cover reduces the rate-of-spread rating on the latter area to that normal for forest types of low fire hazard. Shepard (24) found that Douglas-fir stands 25 feet high to 20 inches in diameter suffered a much lower net loss from fire than very young stands, 3 to 25 feet tall. The net losses for three size classes of stand are as follows:

	<i>Net loss (percent)</i>
Class 3, 25 feet high to 6 inches d. b. h.-----	0.057
Class 4, 6 to 20 inches d. b. h.-----	.063
Class 5, 3 to 25 feet high-----	.921

When cut-over lands burn and reburn at 5- or 10-year intervals, the repeated fires effectively prevent the reforestation that would produce the shade to reduce rate of spread. The thousands of acres of such lands in the Douglas-fir region tend to stay in the higher rate-of-spread classes. Even if fires are now kept from running over such lands, it may take several decades for a forest cover to develop, because of lack of seed supply, impoverishment of the soil, erosion, or other causes.

RESISTANCE-TO-CONTROL FACTOR

The trends of resistance-to-control ratings of burned and unburned cut-over lands shown in figure 9 represent averages of ratings given to each milacre plot after estimating the amount of hand work required to control a fire about the size of the plot. Immediately after a hot

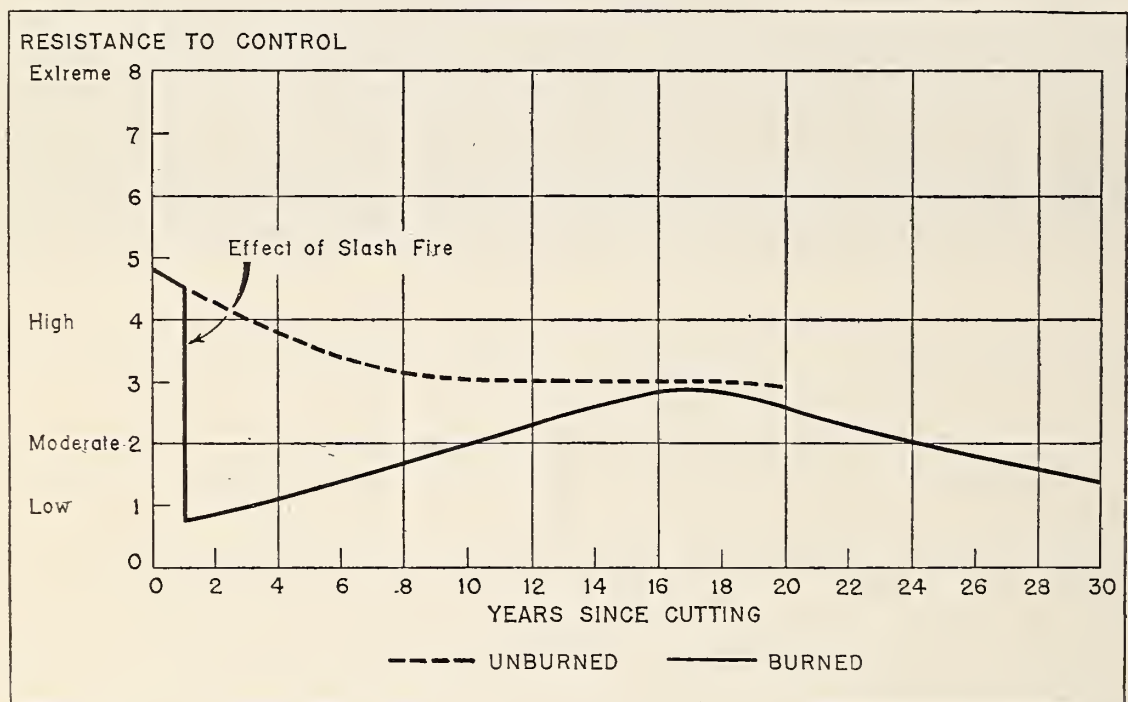


FIGURE 9.—The trends of resistance-to-control ratings of burned and unburned cut-over lands with the passage of time.

slash fire, very little work is required, and the rating at that time would be zero except that the average figure covers some very light slash fires. The gradual increase in resistance year by year is due mostly to the growth of brush, hardwoods, and coniferous reproduction. Vines and weeds also contribute.

Unburned slash offers a difficult fire-fighting problem. The quantity of logs, chunks, poles, limbs, brush, twigs, roots, rotten wood, and miscellaneous fuels that must be cut through or moved to construct a fire trench down to mineral soil is tremendous (fig. 10). At worst, the slash is so deep and tangled that construction of a line through it ahead of a fire is impracticable. Usually it is necessary to take advantage of parts of the area that offer the least resistance, such as old railroad grades, gashes cut into the soil where logs were dragged out, tractor roads, and natural breaks. Even so, a large amount of work is required. Further, slash usually burns with such intense heat that

direct attack is impossible, and resort to an indirect attack adds materially to the total amount of work.

It is significant that, although resistance to control gradually increases year by year on burned and gradually decreases on unburned lands, even after 15 or 20 years the unburned slash areas average slightly higher in resistance to control. This is in sharp contrast to the tendency for rate of spread to be equalized in about 6 years. Study of the small-plot data reveals that, while decay tends to reduce the effect of the most persistent elements of resistance to control, the large pieces of slash of the more durable species, like Douglas-fir and western red-cedar, are not appreciably easier to cut through even after 20 or 30 years. The rank growth of brush and hardwoods that develops in the



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FIGURE 10.—Soon after clear cutting and logging, and before slash burning. Rate of spread and resistance to control are both rated “extreme.”

first 10 years or so on unburned land (fig. 6, *A* and *B*) also tends to increase resistance to control and offsets in part the elements that are decreasing it.

Resistance to control shows wide variations in this region. In general it is much greater in the fog belt, particularly in unburned slash, than elsewhere. This is due to a rapid development of rank vegetation that makes foot travel almost impossible through unburned slash a few years after logging. Type of stand, degree of utilization, or logging methods used may also have an important effect. When sound timber, on ground without undergrowth or windfalls, is cut and logged clean, the operation results in a relatively low resistance-to-control

rating. Defective old-growth timber, however, with dense undergrowth, poles, and many windfalls, makes a slash that will give a relatively high rating. Were it possible to remove all the large pieces of wood from cut-over lands for fuel, pulp chips, or any other use, the resistance-to-control ratings would, in general, be materially reduced on both burned and unburned lands, but with a greater probable effect on the unburned.

McArdle (17) found that—

The slash fire removes from 9 to 49 per cent of the volume of the large pieces, depending upon the severity of the fire and the age of the slash. Ordinarily, a fire in fresh slash probably consumes no more than 30 per cent of the total volume of these larger pieces. If the slash is over 10 years old, it will be drier than when fresh, much of the bark will have fallen, and the fire will remove about 50 per cent of its volume.

A heavy fire consumes at least 95 per cent of the volume of small material. Even a light fire in fresh slash removes about one half of the branchwood and other small pieces. . . .

The fire reduces only slightly the diameter of the larger pieces of slash, but burns entire sections from them. This occurs chiefly where cull logs and down trees or snags are crossed; the amount of wood which a slash fire will consume depends somewhat upon the number of large pieces which are cross-piled by the logging operation.

Since many of the larger pieces of slash are burned in two, there are more logs after the fire than before (averaging about 90 per cent more large pieces), and naturally there is a greater proportion of short lengths than before the fire. After the fire, the large pieces usually are more or less isolated from each other.

This breaking up of coarse slash and diminution of its volume facilitates construction of fire trench, and makes control easier on burned than on unburned land.

Resistance to control is reduced by the subsequent development of a dense cover of conifer reproduction or hardwoods. It is true that in the early stages of its development this cover adds to resistance, because it is just so much more obstruction to be cut through in making a fire trench. But when the new cover has developed to the point that it shades out the mass of brush, vines, and other vegetation next to the ground, and men can work underneath it, the resistance to control decreases. For example, a fully stocked stand of Douglas-fir seedlings 10 years old may look like just so much brush to the fire fighter, but at 20 years these same seedlings may have killed all the tangled mass of low vegetation and shaded out much of the brush, and thus have made fire control easier. At 30 years, under a fully stocked stand, the ground may be free of undergrowth and the principal fire-control job may be digging trench. There are exceptions to this sequence of events; hemlock, for example, often produces thickets of reproduction that for many years remain so dense as to hold resistance to control at a high level. Nevertheless, it can be stated as a general principle that the establishment of a complete crown canopy is the most effective means of reducing resistance to control on a cut-over area. Here again, good silvicultural management results in reduced fire hazard.

RATE-OF-SPREAD AND RESISTANCE-TO-CONTROL FACTORS COMBINED

The fire fighter and the fire-control executive are never in a position to deal with rate of spread and resistance to control separately, as has been done above, but must cope with the resultant of these two factors. This resultant is expressed as a fire-hazard rating, obtained by multi-

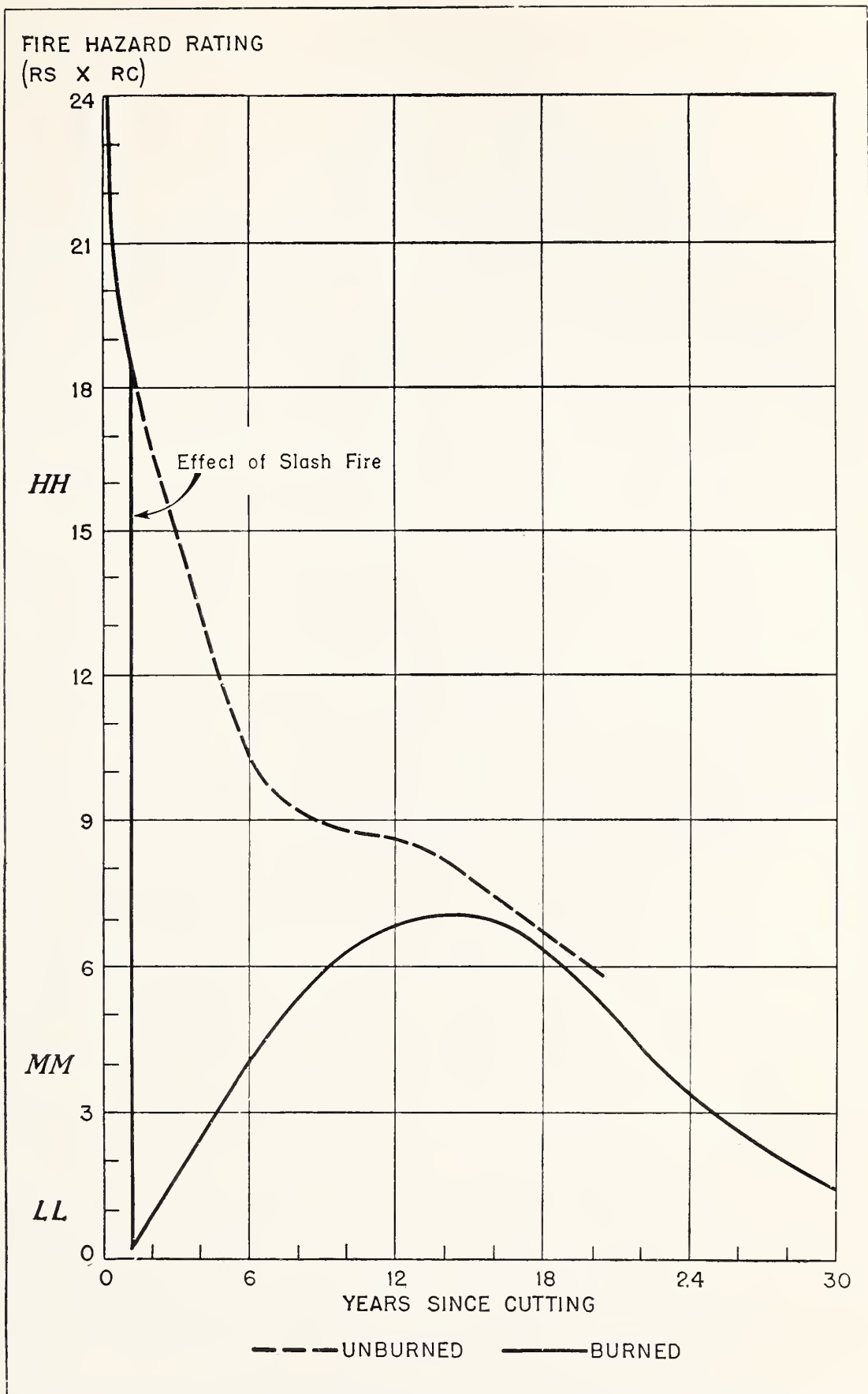


FIGURE 11.—The trend of fire-hazard rating, or the product of rate-of-spread (*RS*) and resistance-to-control (*RC*) ratings, on burned and unburned cut-over lands with the passage of time: *HH*, high; *MM*, moderate; *LL*, low.

plying the rate-of-spread ratings by the resistance-to-control ratings. The practical application of such fire-hazard ratings can be illustrated as follows: If 1 man can control in 1 hour 1 chain of the perimeter of a fire on an area that rates low in resistance and low in rate of spread, 4 men will be required to control 1 chain of fire in 1 hour where resistance is moderate and rate of spread is moderate, since moderate resistance requires twice as much effort per unit of line, and moderate rate of spread produces twice as much line to be controlled. Similarly, 16 men will be required to control 1 chain of fire in 1 hour where resistance is high and rate of spread is high. The trend of fire-hazard ratings on the unburned areas examined in this study over a period of 20 years, and of more than 30 years on the burned areas, is illustrated in figure 11.

This graphic presentation of the effect of slash disposal on fire hazard after logging brings out several important points. Perhaps the most striking feature of the curves is the wide spread in fire hazard between burned and unburned slash immediately after logging and for the next several years. Thus it is shown that 1 year after logging, if 1 man is able to control a small fire on burned cut-over land, about 18 men would be required to control the same-sized fire in unburned slash: at 6 years, 4 men would be required on the burned and about 10 on the unburned land; at 10 years, 7 and 9 men, respectively; and at 20 years, 6 men under either condition.

Wide variations from the trends shown by the curves can be found on individual areas and in different parts of the region. The higher-than-average resistance to control and lower-than-average rate of spread found in the fog belt tend to offset each other, so that the result tends to conform to the curves. Climatic factors are very favorable in that subregion, however, and some of the contingent factors are not so severe. Thus unburned slash is not so serious a fire-control problem there as in other parts of the region and is much more quickly grown over and shaded by vegetation. (Fig. 12.) In those parts of the Douglas-fir region in which the contingent factors are most unfavorable (for example, in parts of the region with long drought period, low relative humidity, and east winds), unburned slash presents an even more serious fire-control problem than is indicated in figure 11.

The combined fire-hazard rating of unburned slash areas is always somewhat higher than the rating of burned slash areas, but after about 10 years the curves come close together and after 15 years there is no particular significance in the differences shown. The divergence in the earlier years is due rather to resistance to control than to rate of spread, as already indicated. Thus any improvement in utilization practices that would remove a substantial amount of the material chiefly responsible for high resistance to control on unburned lands—such as cull logs, poles, chunks, tops, and limbs—would aid in equalizing the hazard on the two types of land.

The material decrease in fire hazard on burned and unburned land which appears after 15 years or so can be attributed largely to the effect of the establishment of a new forest cover. This fact witnesses to the efficacy of prompt and complete reforestation in protecting cut-over lands from fire (fig. 13).

For most of the forest lands except recent cut-overs and non-restocking burns the hazard rating would probably average in the

neighborhood of low rate of spread and moderate resistance to control (expressed for convenience as LM), or a numerical value of 2 on the vertical scale in figure 11. If LM is approximately the normal fire-hazard condition, the fire-hazard rating of land on which slash has been burned is below normal for about 3 years, above normal after the third year to the twenty-eighth year, and after that somewhat below normal again. Hence after about 28 years, cut-over lands on which the slash was burned compare favorably with other forest lands and are again a normal risk from the fire-control standpoint. In contrast to this, figure 11 indicates that for the first 5 or 6 years after logging the hazard rating of unburned cut-over land is very considerably above normal, and for the next 10 or 15 years it is three to five times the normal rating. Thereafter the ratings of the burned and the unburned are probably about the same.



FIGURE 12.—Tract in the fog belt logged 14 years ago and not slash-burned. It reforested promptly, and now hemlock saplings make an almost continuous cover; the fire hazard will soon be back to normal.

AGGREGATE FIRE DANGER

The landowner or land manager in shaping slash-disposal policies and practices should not base them unreservedly on the relative conditions either of unburned or burned areas in any one year. He is concerned with giving the lands adequate protection through a term of years, with the total cost thereof, and with the total benefits of all sorts that will accrue from different treatments.

Unburned slash is some 18 times as hazardous as freshly burned 1 year after logging, and only a third more hazardous 10 years after logging; but what is the aggregate hazard during the period when these lands are a special worry to the owner? Adding together the hazard year by year as expressed in number of men required to control fires, it can be calculated from figure 11 that the unburned would take 120 units of protective effort in the first 10 years from the time of

logging and the burned 54 units—a ratio of 2.2 to 1.0. The aggregate hazard during 20 years after logging would be 196 units on unburned and 120 units on burned cut-over land—a ratio of 1.6 to 1.0. These examples may be taken as an indication of the relative cost of protecting logged-off land of the two categories through one and two decades respectively, assuming that all contingent factors—for example, danger of fires starting—would be the same on the burned as on the unburned land and also assuming that the results would be the same.

It follows, however, that any fire-prevention effort which will reduce the number of fires to be dealt with on the unburned below the number expected on the burned

will tend to equalize the fire-protection job on both. The great danger on most of the lands now being logged is from man-caused fires. It is not humanly possible to prevent all of these, but if the fire-preventive measures discussed later in this circular are enforced very intensively on areas where slash is not burned, the number of fires that start should be greatly lessened, and, in turn, the fire danger on this type of land might be significantly less than that implied in the 2.2 to 1.0 ratio and in the comparisons in figures 4, 9, and 11.

In addition to the factors considered in rating fire hazard on the plots used in this study, various contingent factors must be considered in appraising the total fire danger on burned and unburned cut-over lands. For one thing, cut-over lands for several years adjacent to logging operations and made accessible by logging roads to berry pickers, fishermen, hunters, etc., have a high inception danger. On the other hand, the logging operator's interest in protecting his large investments in railroads, bridges, machinery, timber, and camps from fire and in avoiding shut-downs caused by damage to such equipment, causes him to undertake added precautions and preventive expendi-



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FIGURE 13.—Sample plot used in this study that was logged and slash-burned 11 years ago. It has a rather dense accumulation of flashy fuels. The fire hazard will be back to normal only when the young Douglas-firs make a continuous cover and shade out the undergrowth.

tures. These should largely offset the increased opportunity for fire to start on cut-overs. For another thing, specific cut-over lands, both burned and unburned, may be subject to elements of fire danger not included in the standard set of conditions assumed in rating the plots, such as extreme weather conditions, the effect of steep slopes, and the presence of snags.

Not only is the inception danger higher on cut-over land than on timbered land but other contingent factors tend to make the aggregate fire danger higher. Figure 7 confirms common knowledge that fuels are drier on cut-over than on timbered lands. Also, the fuels are more exposed to the effect of the wind and flashy fuels are more abundant. Cut-over land dries out more quickly after rain or damp weather. This last is extremely important because it means that there are more days each season on which fires will burn on cut-over land than on timbered land. Thus in addition to a higher inception danger, cut-over land also has drier and more dangerous fuels and more days of high-fire danger per season than timbered land.

Since fire control in unburned slash is, in the first years after logging, many times more difficult than on areas from which the slash has been burned, and fire control on both burned and unburned cut-overs for 20 to 30 years is more difficult than on most timbered lands, the land manager should gage his fire-control efforts accordingly. This is certainly true whether or not the numerical values in figure 11 are an exact expression of the relative fire hazard on burned and unburned cut-overs. The trend of the curves taken in conjunction with the contingent factors mentioned indicates that the aggregate hazard on unburned is greater than on burned cut-overs and that both are a more difficult fire-control problem than most timbered lands. It is also known that reburning prevents prompt reforestation of cut-over lands, keeps them nonproductive, and tends to keep them in a state of high fire hazard; therefore, they should be given very much more protection from fire than timbered lands.

It is pertinent to observe that the many thousands of acres of high-hazard cut-over lands existing today in the Douglas-fir region as a result of repeated fires or lack of a seed supply or both will remain in their present unproductive and unsatisfactory fire-hazard condition indefinitely unless the fires are stopped and a forest cover develops. In some places planting may be justified. A part of the expense of planting might even be recovered in the resulting reduced cost of fire protection. If the areas are not reforested, cost of fire protection will remain high, and this high cost will be incurred on land that is not productive.

It is also pertinent to observe that large, continuous areas of cut-over land are a very special conflagration hazard because of the possibility that a fire will spread to large size before it can be controlled, especially if there is an abundance of fuel such as unburned slash. Furthermore there is always the danger that a fire having such momentum, will start a conflagration in adjacent green timber. As cutting progresses in any locality the conflagration hazard increases, particularly when lands of several operations merge.

Thus it might be good practice to leave unburned reasonably small isolated bodies of slash, but bad practice to allow extensive, continuous areas of unburned slashings to accumulate and build up the con-

flagration hazard. It is wise to consider the ultimate extent of highly inflammable areas, as well as other factors of fire danger, and plan to keep the conflagration hazard to a minimum.

In conclusion it may be said that although it is undoubtedly more difficult and therefore more expensive to carry an area of unburned slash until it has reforested than it is to carry burned land for the same period of time, this should be done wherever the finances of forest management or the compensating advantages justify it. Once the forest manager decides that it is good business to carry his land with unburned slash on it, he will gage his efforts year by year by some such trend as that shown in the upper curve in figure 11. For the first few years, much care and effort will be required. Prevention measures will be extremely important. Elimination of trespass will be a necessity. Better utilization would help. After 15 or 20 years the cost of protecting unburned areas might not be greater than the cost of protecting comparable burned land.

RELATION OF SLASH DISPOSAL TO REFORESTATION^s

Before deciding on any slash-disposal policy, the forest manager should have an accurate understanding, based upon a knowledge of his own local conditions, of the relation between slash-disposal practice and natural reforestation. This relation is not always obvious.

The impression has long existed in the minds of many in the Pacific Northwest that slash burning, by removing the debris and exposing the mineral soil, is beneficial if not actually necessary for the natural regeneration of Douglas-fir. This is now known to be far from the truth. In fact, from almost every point of view broadcast slash burning is in some degree detrimental to natural reforestation.

EFFECT ON SEED TREES AND REPRODUCTION

Single trees or groups of trees are sometimes left intentionally to provide a seed supply; often trees that may accomplish the same purpose are left uncut merely because they are low in marketable value. In either case, they must survive the logging operations, the slash fire, and other destructive forces to be effective. Experience with single seed trees of Douglas-fir on national-forest timber sales shows that about 75 percent of them die within 10 years as the result of slash burning, supplemented by insect attack, and wind throw. Even a larger percentage of the smaller, understory, and thin-barked trees are killed. The loss of any potential seed-bearing trees must be considered detrimental to natural regeneration, for on clear-cut areas there is almost always a dearth of seed.

Groups of seed trees and patches of immature timber can, with special effort, be saved from damage during slash burning, but often they are badly scorched and their effectiveness is impaired. Slash burning also is apt to kill trees on the margins of bodies of uncut timber that would otherwise serve as a seed source.

A forest often throws seed just before it is cut that would assure reforestation if not destroyed in slash burning; it is often some months, occasionally a couple of years, from the time the trees are

^s In preparing this chapter, data from both published (S. 9, 10) and unpublished studies by L. A. Isaac, of the Pacific Northwest Forest Experiment Station, have been largely used.

felled until the slash is burned. Should seedlings start in the meanwhile, the slash fire would inevitably kill practically all of them. Experiments indicate that some seed survives slash burning, but the presumption is that, on areas logged just as the seed becomes ripe and burned later in the same year, most of the seed is destroyed. Winter- and spring-logged areas are usually not burned until the following fall; meanwhile, the seed cast previous to logging if not rotted or eaten by animals has germinated, and the young seedlings are not likely to withstand the baptism of fire. If there is no source of further natural reseeding, the prospect of natural regeneration is then lost. Even if there is a seed source, time is lost until the next seed crop and favorable germinating season. On areas burned in the spring following logging, it is to be expected that more seed will survive the fire than in the case of fall burning, because it will not have germinated and spring fires do not burn so deep in the surface litter.

It is sometimes asserted that failure to burn slash increases the ratio of hemlock to Douglas-fir in the reproduction. Where advance reproduction of seedlings or saplings occurs in the virgin woods this may be true, for there the shade-tolerant hemlock has the advantage of the light-loving Douglas-fir. But it is not clear that reproduction that starts after logging will display a similar tendency. Theoretically, hemlock might survive on nonburned land and not on a burned tract. Yet on areas where conditions are optimum for hemlock, the next crop will have a high percentage of that species regardless of burning or not burning; on other areas Douglas-fir is inevitably supreme; elsewhere, red alder may come in temporarily in competition with the conifers. It is very difficult to change the mixture of species in a virgin forest region where there is no control over the seed supply.

EFFECT ON ANIMAL ENEMIES OF REFORESTATION

The white-footed mouse, because of its proclivity for eating seeds and seedlings, is an arch enemy of reproduction. Contrary to expectation a slash fire does not rid an area of mice. In fact, slash burning appears to encourage the small rodents on some areas, making more available the seed of trees and other vegetation that fall after the surface litter has been burned off. Rabbits, which are often damaging to tree seedlings, are attracted to some areas by the succulent vegetation of sprouts and herbs that comes in immediately after the burn. Full appraisal of the rodent factor on slash burns must await the results of further studies which the Fish and Wildlife Service (formerly the Bureau of Biological Survey) of the Department of the Interior is now making.

EFFECT UPON THE SOIL

It is known that slash burning affects the soil in a number of ways, many of them unfavorable to tree reproduction, but this knowledge is at present incomplete. Obviously, it is not necessary here, as in some other forest types, to burn in order to expose mineral soil and make a favorable seedbed, for the duff layer in the Douglas-fir and spruce-hemlock types disintegrates about as fast as it accumulates and is usually thin. Moreover, the surface-harrowing effect of logging usually exposes enough mineral soil, even without slash burning,

to favor the establishment of seedlings that depend upon that type of seedbed.

Briefly, the effects of burning upon the soil appear to be as follows:

(1) Fire tends to blacken the soil surface with bits of charcoal, and this sufficiently increases maximum daily soil-surface temperatures during hot weather to kill an additional number of the very young seedlings (9). With an air temperature of 85° F., a yellow unburned soil had a surface temperature of 125°, but a burned and blackened surface had a temperature of 140°. In one instance, when the surface temperature reached 143°, the mortality among Douglas-fir seedlings was 47 percent.

(2) Changes in soil structure that may be detrimental to seedling growth sometimes result from slash burning. In a test (10) on the Wind River Experimental Forest, 89 percent of the organic matter in the duff, or 25 tons per acre, was consumed in a single slash fire. This material has the capacity to absorb moisture and to act as a mulch, and its loss definitely makes the soil itself less favorable for seedling growth on certain sites. The concentrated heat of a slash fire, as where crossed logs are burned out, so breaks down the colloidal structure of the soil that even planted trees cannot survive on these spots. In observed instances, normal soil structure was gradually regained and trees subsequently planted as replacements survived, but even after 10 years they did not prosper so well as trees planted where the burn had been less intense.

(3) There is dispute among investigators as to the final effect of slash burning upon soil fertility. Certain nutrients are consumed, others carried off in smoke, and others released in the surface soil for ready use by plants. Much of the valuable nitrogen stored in the leaf litter escapes in the process of combustion and is lost to subsequent vegetation. Burning increases the supply of mineral nutrients in the surface soil, but in this climate much of this material is leached away rather soon and the net beneficial effect on seedling growth is questionable. Burning changes the highly acid condition of the surface soil to an alkaline condition, which in turn favors nitrifying organisms. Whether this gives the greater aid to competing vegetation or to Douglas-fir seedling establishment is still uncertain.

Although excellent reproduction is often found on heavily burned areas, it is safe to say that slash burning affects the soil unfavorably for reforestation, largely through its effect on structure, stability, and moisture-holding capacity. It is well to remember that a hot slash fire is very much more destructive to the humus, the soil, and the seeds on the ground than an ordinary forest fire in virgin timber, because of the far greater volume of fuel on the ground and the consequent greater surface heat.

EFFECT ON WOODY AND HERBACEOUS VEGETATION

Where there is a large amount of perennial woody vegetation, such as vine maples, willows, huckleberry, salal, and understory worthless hemlock saplings, which will be killed or at least temporarily set back by burning, the fire may actually be beneficial in giving new tree seedlings a chance at light. Tests show that where the cover is continuous seedlings are inhibited from starting. The underbrush

is rarely too dense for reproduction immediately after logging, however, except on certain sites, particularly on the west slopes of the Coast Range.

Moderate shade favors reforestation, by protecting tender seedlings from extremes of heat or cold and lessening evaporation from surface soil. Slash fires which kill woody vegetation that is beneficial rather than competitive are unfavorable to reforestation.

Following slash burning there is ordinarily a marked change in the composition and density of the woody undergrowth and herbaceous vegetation—a decrease in the shrubs and herbs characteristic of the virgin forest and a notable increase in the annual herbs. Information is not conclusive as to how much this change in vegetation affects tree reproduction but it appears that it is harder for reproduction to compete with a dense growth of senecio, fireweed, and bracken than with the vegetation characteristic of similar unburned areas. Sometimes both burned and unburned areas develop mats of vegetation that are unfavorable for seedling establishment, but more often there is enough space available for tree seedlings either on burned or unburned ground. Whether the net effect of slash burning in changing the herbaceous cover is favorable or unfavorable to reforestation has not been proved; undoubtedly the effects vary with local conditions.

SLASH AS AN OBSTRUCTION AND AS A SOURCE OF SHADE

The finer logging debris that would be consumed in a slash fire has a dual role; it may operate to keep seeds from reaching a favorable germinating bed and seedlings from reaching the light, and it may furnish beneficial shade to tender seedlings. Though the volume of slash is often enormous, the class of material that would be consumed by the fire is patchily distributed over the ground, usually leaving plenty of spots where seed could find exposed soil and seedlings become established and make a reasonably well-distributed stand. It is not thought, therefore, that removal of slash by burning, of itself, promotes reforestation. Both the coarse material and the finer slash give dead shade, i. e., they give shade without competing for soil moisture as a bush or tree does; this is an ideal influence for the establishment and survival of reproduction (9). On severely dry sites, seedlings are commonly found on the shady side of piles of debris, logs, or stumps. Burning naturally lessens the amount of dead shade. It would, therefore, seem that the unburned debris on most sites is physically more beneficial than detrimental to tree seedlings.

COMPARATIVE RESTOCKING OF BURNED AND UNBURNED LAND

A measure of the chances for natural reproduction on unburned areas versus burned areas was obtained through observation of a series of sample plots on six widely separated tracts of logged-off land in the Douglas-fir type, part of each of which had been slash burned and part unburned. These plots were logged and burned in 1926 and were observed annually from then until 1933, a period without exceptionally heavy seed crops. At the end of that time the unburned areas had $5\frac{1}{2}$ times as many seedlings per acre as the

burned. Most of the unburned tracts were well stocked, while all the burned areas were either nonstocked or poorly or medium stocked. The results are shown in table 2.

Confirmation of the above is indicated by a count of reproduction made by L. A. Isaac in 1926 on a dozen recently logged tracts in Oregon most of which had been slash burned, but upon which there were patches of unburned slash. From one to three growing seasons had elapsed between the fire and the time of the examination. The seedlings were tallied on a strip 6.6 feet wide aggregating 31½ miles in length, well distributed over the 12 areas. The seedling count per acre on burned and unburned areas for one, two, and three growing seasons since logging and burning is given in table 3.

TABLE 2.—*Reproduction 1 year old and older per acre on burned and unburned surfaces 8 years after logging*

Area	On un- burned surface	On burned surface	Area	On un- burned surface	On burned surface
	<i>Number</i>	<i>Number</i>		<i>Number</i>	<i>Number</i>
Westfir, Oreg.:			Hoodspout, Wash.:		
Area 1	544	352	Area 1	640	288
Area 2	1,760	96	Area 2	720	200
Wilark, Oreg.	1,472	11			
Ostrander, Wash.	280	80	Average (weighted)	808	146

TABLE 3.—*Seedling count per acre on 12 logging operations in Oregon, from 1 to 3 growing seasons after slash burn*

Elapsed grow- ing seasons	On burned ground	On un- burned ground
	<i>Number</i>	<i>Number</i>
1	53	1,333
2	103	1,557
3	274	2,600
3½	1,100	5,900

¹ Seed supply abundant from seed trees.

Another measure of the average chances for natural reproduction of conifers consists of records of percent of areas stocked on 41 of the unburned and 77 of the burned tracts upon which the study of comparative fire hazard was made (fig. 14). Although the burned plots were not paired with exactly comparable unburned plots, and coastal areas were averaged in with Cascade Range areas, it is thought that the comparison is significantly indicative of a general region-wide relation of natural reforestation to slash burning for areas that have had quite a number of years in which to reforest. Were the data more ample, the curves would undoubtedly have been better defined.

Figure 14 shows that the unburned areas were consistently better stocked. Seven years after burning they averaged 50 percent, against 25 percent for the burned areas. With time both classes of areas improved in stocking and the difference between them in degree of stocking diminished. If reproduction had been recorded by number

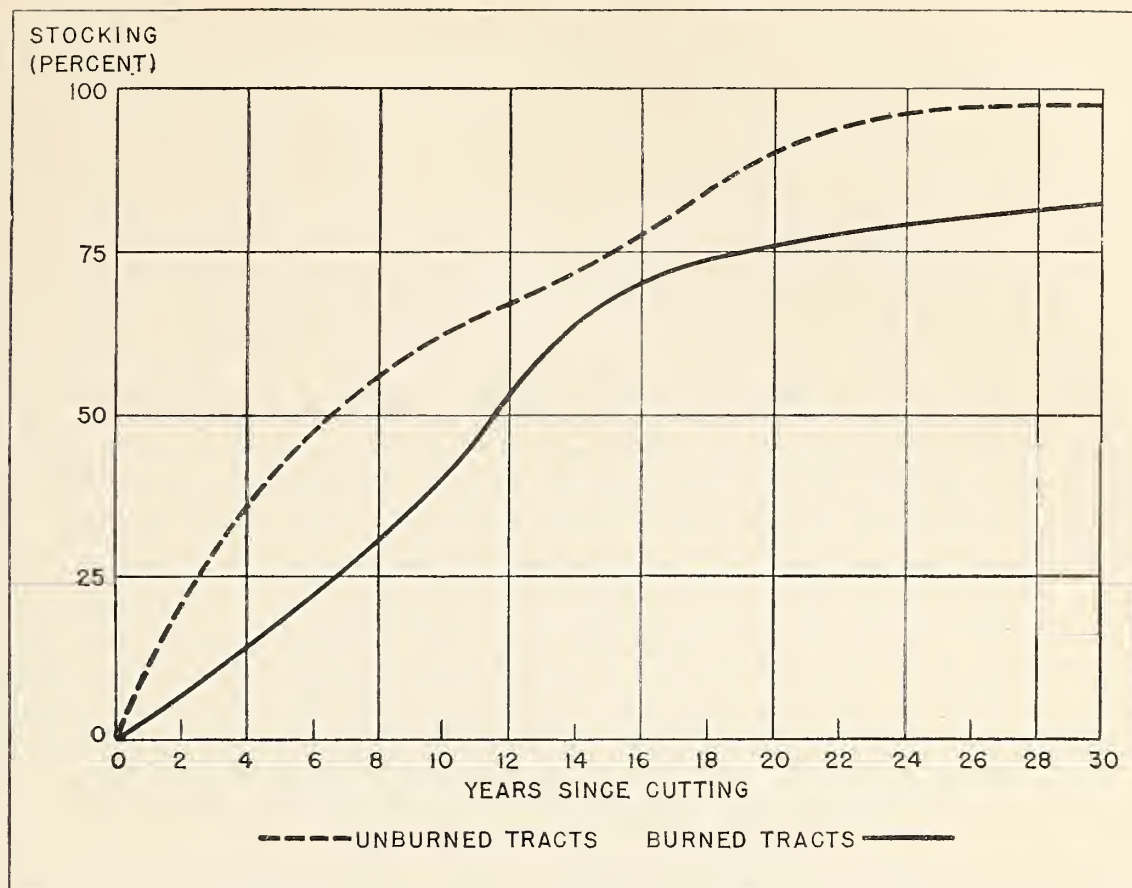


FIGURE 14.—The average percentage of stocking with tree reproduction on 77 slash-burned areas and 41 unburned areas on the Cascade Range and coastal region of Oregon and Washington at various periods after logging.

of seedlings per quadrat instead of in percentage of full stocking, the spread between the burned and the unburned tracts would have been even greater, because the higher the stocking the larger the number of seedlings per quadrat. It is significant that in the first two decades after logging, as a general principle, unburned areas attained a certain degree of stocking from 3 to 5 years quicker than burned areas. These data represent average conditions and may be relied upon as a general indication of results to be expected; but many instances could nevertheless be cited in which slash-burned areas have reforested satisfactorily immediately after burning.

In the preceding discussion of the relation of slash disposal to reforestation, "unburned" means perfectly protected from fire and "burned" means subjected to but a single slash burn immediately following logging. If slash is burned several years after logging, the deleterious effects upon reforestation are much greater. And, of course, if a second fire runs over an area, every unfavorable effect is magnified and the chance for successful natural regeneration is diminished or indefinitely postponed. Similarly, if an accidental fire runs uncontrolled in the summer over an area that was supposed to be left unburned, the results are likely to be worse than those that would have followed prompt intentional burning in the fall.

Artificial reforestation will ordinarily not be practiced as a silvicultural measure following logging; it should not be necessary when natural regeneration, which is much cheaper, can be provided so easily. Planting will be employed chiefly where a quick cover is desired for aesthetic reasons, soil conservation, or water protection,

where there is good security from fire, and where its cost is clearly justified. It would seem advisable to plant only where slash has been burned, so that the planting investment may benefit by the minimum of fire hazard. Ordinarily planting would only be done after one or more burns had made it obvious that natural regeneration would be impossible or long delayed.

OTHER EFFECTS OF SLASH DISPOSAL

SOIL AND WATER CONSERVATION

The common beliefs, that there is little or no danger of soil erosion following logging in the Douglas-fir region because the ground is so quickly reclothed with brush and herbage, and that water conservation is not a vital consideration because rainfall is very abundant, irrigation is little practiced, and freshets are well taken care of by most of the river channels, are not without basis; but it is nevertheless true that soil erosion and water conservation should have consideration in the management of logged-off lands in this region.

Although no original studies have been made of the relation of slash-disposal practice to erosion and the regimen of streams in the Douglas-fir region, general observations indicate that both gully and sheet erosion follow clear cutting on steep slopes, and that they are much worse in some soils than others. Broadcast slash burning, with its exposure of the mineral soil, is bound to be conducive, temporarily at least, to quick run-off and erosion. It is obvious that a well-distributed layer of duff and slash acts to retard erosion and may hold back run-off. As brush, weeds, and young trees invade burned-over land, a mantle is formed that after a few years may give the soil as much protection against erosion and as absorptive a surface as that on unburned slashings.

The accelerated erosion that follows slash burning, though it continues for only a few years, cannot but be detrimental because it removes the valuable topsoil and so affects future forest productivity. Likewise, on a clear-cut watershed, accelerated run-off might follow slash burning to an extent that, within a short term of years, would be seriously damaging. Water for domestic use may be so affected by sediment and dissolved ash from slash burning as to make it undesirable.

Erosion and rapid run-off are most serious on the steep slopes which will be logged more and more in the future, as timber operations perforce penetrate the more rugged, mountainous parts of the region. The forest manager, particularly of public lands, should realize that slash burning does have some effect on erosion and quantity and quality of run-off, and in some special cases this fact may decide the policy of slash disposal.

GRAZING OF DOMESTIC STOCK

The grazing of livestock as a temporary use of logged lands may be entirely compatible with the major use of timber growing. The land manager should consider the possible benefits from grazing and the possible disadvantages and lay his plans accordingly. Grazing

may bring in some annual revenue until the tree growth becomes so dense as to preclude it. Apparently heavy grazing by sheep lessens the fire hazard, by removing some of the herbage that would otherwise accumulate as tinder. However, an experiment⁹ in the Wind River Valley, Columbia National Forest, indicated that within a short term of years the unpalatable bracken fern, which makes a bad fire hazard, increases at the expense of the other herbaceous plants, leaving the area, insofar as the tinder from the herbaceous vegetation is concerned, about as dangerous as though there had never been any grazing. Barring repeated fires, tree growth and its accompanying shrubby growth should develop on cut-over land to such an extent as to make grazing impracticable in 15 to 20 years after logging.

When a land manager decides to graze his cut-over land he will naturally want to take those measures, particularly as regards slash disposal, that will favor grazing and at the same time have no unfavorable effect on fire-hazard, reforestation, and other conditions. Slash burning is undoubtedly beneficial from the stockman's viewpoint. It makes the range easier of access for sheep or cattle, and it encourages at the start the type of weed forage (especially fireweed) which is more palatable than the vegetation that usually persists from virgin forest conditions.

FISH AND GAME MANAGEMENT

Severe slash fires that span small creeks are hard on fish. They kill the overhanging shrubs that shade the water, they may temporarily render the water lethal, and they may actually kill small fry in shallow water. Where encouragement of fish life is an objective, the forest manager should not forget the possible effect of his slash-disposal practice thereon, and should at least try to prevent slash fires from burning to the very edges of trout waters.

Fall slash burning is not thought to have any very direct relation to game management; spring burning might be disastrous to nesting game birds. The food supply for game birds and animals is probably better on unburned areas than on burned areas, because of the great abundance of shrubs on the former, which give seeds to birds and browse to deer.

AESTHETICS

Logged-off lands are unsightly at best and on areas of high recreational use, as near campgrounds and along highways, the land manager, particularly on public lands, should not forget appearances and should gage his practices so as to offend public taste as little as possible. The method of cutting can itself be more aesthetically destructive than anything else; but where clear cutting has been practiced, well-conducted slash disposal will prevent the maximum of unsightliness; for example, in the vicinity of campgrounds and immediately adjacent to highways, it may be found good policy to burn slash in piles in order to avoid having a broadcast burn come right to the edge of highway or campground.

⁹ REID, E. H., ISAAC, L. A., and PICKFORD, G. D. PLANT SUCCESSION ON CUT-OVER, BURNED, AND GRAZED DOUGLAS FIR AREA. Pacific Northwest Forest and Range Expt. Sta., Forest Res. Notes 26, 1938. [Mimeographed.]

INSECT INFESTATION

In some forest types insects injurious to living trees multiply inordinately in slashings, and slash burning is, therefore, to be recommended as a means of forestalling insect epidemics. This does not seem to be the case in the Douglas-fir region. The Division of Forest Insect Investigations of the Bureau of Entomology says (25) :

In the region along the Pacific coast reports on observations of the death of Douglas fir from the attack of insects that breed in slash are so infrequent that they can be disregarded.

Hence slash-disposal policy in this region need take no account of insect enemies of forests.

PRINCIPLES OF SLASH BURNING

The technique followed and skill employed in slash burning may be sufficient under any circumstances to spell the difference between success and disaster. Success implies (1) burning promptly after logging, (2) keeping the fire out of uncut timber and seed-tree groups, (3) preventing the reburning of areas previously slash burned, and (4) getting an effective clean-up of debris. The first step is to decide whether or not slash burning will accomplish its purposes of reducing the fire hazard and lowering the cost of logged-off land protection without offsetting disadvantages (13, 16). If it is decided that the area is to be broadcast burned, the operator should recognize that slash burning is an integral part of the operation and should organize his logging so that each year's logged area is ready for burning in reasonably small blocks when the burning season comes around. Too much emphasis cannot be placed upon the importance of planning the logging so that the slashings may be promptly and safely burned. This advance planning takes the following form :

(1) Distributing the settings so there will not be large continuous areas to be burned at one time; staggered settings are advantageous.

(2) Laying out the settings so that a current season's burning area has definite boundaries that take advantage of natural barriers for stopping the fire, such as streams, roads, and unfelled timber, and so that the next year's logging area, also, can be safely burned.

(3) Timing the logging of each burning unit so that machinery may be out of the way by the time the burning season arrives, and felled and bucked timber will not adjoin an area to be burned.

It is assumed in this discussion that broadcast burning is the only method of slash disposal that can be practiced. After clear cutting, the volume of debris is so enormous that any possible method of windrowing or assembling the slash, even with the use of machinery, at present seems impracticable. Further, any attempt at spot burning or partial burning is likely to result in a broadcast fire. When larger margins of profit in Douglas-fir logging permit greater expenditure on slash disposal, some modification of spot burning may become practicable. For example, machinery might be employed to assemble the larger masses of debris before they got wet and the burning might be done with the aid of some sure-fire ignition ma-

terial at a time when the ground was so wet that fire would not run. Experimentation with such methods is desirable, even though they are not now practical. The land manager must decide whether it will be more effective to spend more money than at present for slash disposal or for direct protection.

One large company formerly followed the practice, much used in the redwood region, of doing most of its felling in the winter, burning its slashings in the spring before the felled trees were bucked into logs, putting out smoldering fires, and so logging on burned-over ground (11). This practice has few adherents and little to commend it in the Douglas-fir region.

Much has been written on the technique of broadcast slash burning following clear cutting in the Douglas-fir region (2, 6, 21, 27, 29), this discussion will, therefore, be limited to a summary of the outstanding points.

SEASON OF BURNING

As has been pointed out already, promptness is of basic importance, since thereby the slash hazard is got rid of at the first opportunity, reproduction is favored as much as possible, and a cleaner burn is obtained before the needles have fallen and green herbage grows up.

Only for a very few days in the fall and again in the spring is the slash dry enough and other fuels moist enough at the same time so that fire can be controlled. Most operators prefer fall burning, and plan accordingly. They like to burn when the fire will cover the area quickly, for a free-burning fire—provided there is no wind—is easier to steer and to mop-up after than a smoldering fire that leaves much unburned timber and hold-over fire behind. The great disadvantage of spring burning is the danger that hold-over fires may break out in the dry summertime. Another disadvantage from the hazard-reduction viewpoint is that a spring burn is not a clean burn; this is, however, an advantage from the point of view of reproduction, seed-tree survival, and soil conservation. Spring burning also obviates the danger of carrying an unburned slashing through the summer. If spring burning is practiced special precautions must be taken to extinguish all fires before the dry season (23).

The arguments for and against spring burning vary with site and with local climate. Dry sites might be successfully burned-over in the spring when wet land could not be. In the southern part of the region, where good burning weather comes quite early in the spring and is quite sure to be followed by good rains, spring burning is safer than in more humid districts, where no spring burning is possible until just before the long summer drought. Haefner (5) cites several instances of slashings in western Oregon burned cheaply and successfully in April and May. It has been suggested that spring burning may be successful with young Douglas-fir (red fir) where it would not be with old growth (yellow fir). Unless the operator is prepared to be thorough in mopping up lingering fires the safest practice is to burn in the fall. Only where spring burning can be done safely, may it have a definite place in logged-off land management.

CHOOSING THE DAY FOR BURNING

As to whether it is better to burn early in the fall, just prior to the first rain (4), or later in the fall, between rains, opinions differ. One experienced operator says (15), "To set a slashing fire previous to a general fall downpour should be a penitentiary offense"; another experienced operator in the same State (26) mildly advocates August burning. Those advocating early burning assert that it gives the cleanest, quickest burn, that high winds are less probable than later, and that some years the slash never gets dry enough after the first early rain. The majority of protectionists and operators prefer burning after September 20 or October 1, because there is almost always dangerous fire weather in mid-September and experience has well proved that slashings burned then are likely to be expensive to patrol and may give serious trouble. It is an uncommon season when there is not a spell or two of good slash-burning weather after the first rains. The operator must watch for these and keep well informed as to the Weather Bureau's forecasts and the condition of his slashings, so that instantly at the end of a dry spell and on the eve of the next rain he can fire the area. Such an opportunity may continue for only a few hours. It is well to avoid setting fire when winds are present or predicted. Since the fall rains begin earlier at the north end of the Douglas-fir region than in the south, the burning will naturally be earlier by the calendar in Washington than in Oregon and earlier along the coast than in the interior.

ADVANCE PREPARATION

To do a good job of burning the following advance preparations are necessary:

1. A plan of action should be reduced to writing and approved by the logging superintendent or land manager.
2. Snags should certainly be felled, as now required by the Oregon law and as stipulated in the Forest Practice Handbook of the West Coast Lumbermen's Association.
3. Timber around the edges of the area to be burned should be felled inward, so that there may be no slash to lead the fire into green timber or into areas once burned.
4. Machinery should be moved off the area before the beginning of the burning season, so that there may be no cause not to burn promptly when the right weather comes.
5. Pumps, tank cars, hose, and hand tools should be put in working order to use at a moment's notice.
6. If the fire cannot be stopped by natural firebreaks, fire lines should be constructed along one or more sides of the area according to circumstances—near the top in steep country. Some operators put a line just inside the uncut timber bordering a slashing; others build the line 100 feet or so inside the edge of the slashing, and then backfire from that. Fire lines around blocks of seed trees or islands of immature timber may be necessary. Fire-line construction is much simplified if tractors can be used with plows or bulldozers.
7. A crew large enough to do fire fighting should be on call when the burning is done. When camps are closed down it is dangerous to burn with only enough hands to set the fires unless there are men nearby who can be employed for fire fighting should that be necessary.
8. Cleaning out should be thorough around bridges, trestles, camps, and oil tanks.
9. A burning permit should be obtained from the local warden if the work is to be done in the closed season.

These advance preparations cost money, but operators should realize that it is money well spent to insure against the fire escaping and to make sure of abating the hazard promptly.

SETTING THE FIRES

Late afternoon or evening is a good time to set the fires, if the slashing is dry and rain is not too imminent, or earlier if conditions are favorable for controlling the fire. The foreman should consider topography and wind, setting fires on the uphill and leeward sides first, in order that these more dangerous edges may be burned out before the great mass of the slashing is afire. If one crew ignites the upper and lee edges of the slash and another sets a parallel line of fire about 50 feet within the slash area, this will burn out a strip along the uphill and lee edges before more is ignited. Possibly several such strips will have to be burned out progressively across the area. Fire that tends to cross the line can readily be extinguished, preferably with water from previously laid hose lines or from back-pack tanks. After the dangerous edges have been burned out the central part of the slashing should be fired as rapidly as possible, so as to pull the heat and sparks toward the center of the area. When the central mass of the slash is well ablaze the flanks and then the downhill and windward edges should be backfired.

The ignition crew should be experienced men, equipped with blow-torches or back-pack pumps filled with oil. They must work quickly and by a coordinated plan understood by all. Good fire-setting equipment makes it possible to ignite a slashing which is still too damp to ignite easily if at all from match or firebrand.

The foreman must give very clear instructions as to where each man is to work and when he is to do his particular job of fire setting. He must know at all times where his men are, for the work is dangerous, especially at night.

MOP-UP

The slashing will burn over in a few hours, but stumps, cull logs, and piles of debris, such as landings, will smoke for days regardless of the weather. Spot fires may have been started outside the fire line. Unless heavy rains ensue at once, a few men should be assigned to work around the edges of the burn, put out fires that might cause trouble, and work the area until the last spark is out. If dry or windy weather should come before this, the patrol should be increased. Many disastrous conflagrations have occurred late in the fall because slashing fires that seemed safe broke out and spread.

ESSENTIAL STEPS IN PROTECTING LOGGED-OFF LANDS

A study of the fire records for the years 1926 to 1930, inclusive, indicates that lands cut over since 1920 were burning over at the rate of 3.9 percent annually, not including the slash-disposal fire. This is probably an underestimate, because some intentional slash fires that spread to once-burned land in that period were not reported as forest fires. Some areas have burned over repeatedly at short intervals, others have escaped a second fire altogether.

The recently completed forest survey of the Douglas-fir region¹⁰ indicates that the recent cut-overs (other than those on national forests) included during this same period 37 percent of the burned acreage of the region, although they compose only 11 percent of the area of all types. On the other hand, old-growth Douglas-fir with 14 percent of the forest acreage had but 11 percent of the burn. The higher present value and lower inflammability of old-growth timberland, in contrast with the lower value and much greater inflammability of the cut-overs, account for the tremendous disparity in the results of fire control on the two classes of land. Cut-over lands are also more exposed to fire-starting agencies.

Recurring fires do not lessen the fire hazard except temporarily. (Fig. 15.) Reburning of logged-off lands after the slash has once been burned is indefensible on any ground, unless the tract is definitely to be cleared for agriculture or put to some use other than forest production.

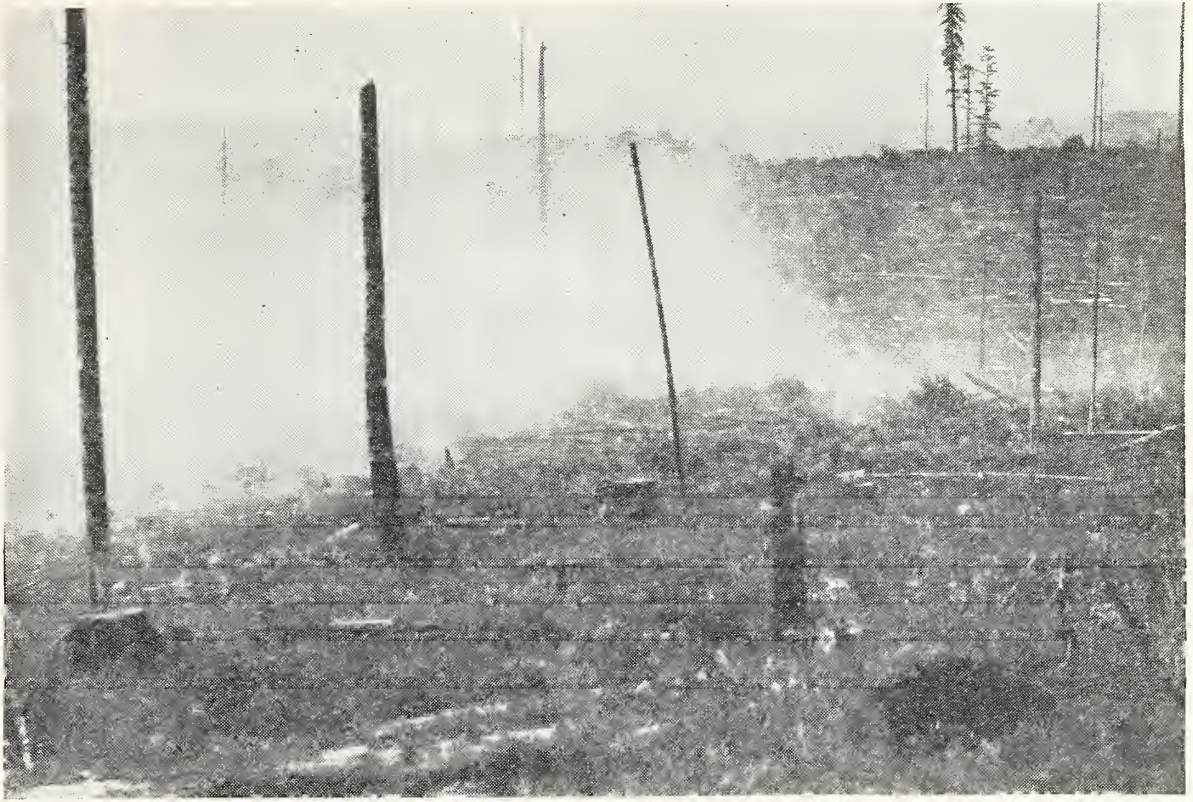
Logged lands, next to old burns, are recognized as being the most difficult to safeguard from fire, even after the slash has been burned. Unremitting and intensive protection of all logged-off lands, from the time of felling until a heavy continuous forest cover is restored, is the prime requisite of forest management in this region. Unless fires are prevented (other than slash burning), no new forest can be established; and unless a new forest is established to shade out the inflammable herbage and shrubbery, the acute hazard will continue indefinitely. It is wise policy, therefore, and economy in the long run, to give logged-off land such intensive protection at the start that the period of acute hazard may be short and a new timber crop be obtained without delay.

The tripartite organization for forest protection—private, State, and Federal—theoretically gives protection to all lands, whether timberclad or in stumps. More protection money per acre is spent on cut-over lands than on virgin timberland, but such expenditures are not yet in proportion to the great difference in fire hazard. Cut-over lands are at present inadequately safeguarded.

Considering the inadequate protection of cut-over lands, the indifference of many landowners to the future of their lands, and the many ways in which cut-overs can get afire, it is no wonder that they have a bad record for burning and reburning. To overcome some of these difficulties, changes in the ownership pattern, in the attitude of owners, and in public policy may be necessary, but these matters are not within the province of this circular. Any owner who is holding land for permanent forest production must give it efficient protection or his investment will be wasted. The present policy of having the public share in the cost of protecting privately owned reforesting lands seems sound and likely to continue. The important point is that, in view of the unsatisfactory nature of past results, much more money must be appropriated from some source to give adequate protection to logged-off lands than has been spent heretofore.

It is impossible within the scope of this circular to give thorough treatment to the technique of forest protection; what follows is no more than an outline of the essential steps already in effect on the

¹⁰ See footnote 5, page 5.



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FIGURE 15.—Area clear cut and burned in 1927 reburning in 1932, with plenty of fuel for the fire to feed upon. Much more intensive protection is necessary to make these lands safe for reforestation.

best-protected lands of the region, but it includes fundamental necessities of any protective organization, whether directed by the individual owner, a fire-patrol association, the State, or some unit of the Federal Government.

FIRE PLAN

There should be a fire plan for each protection unit, stipulating the protective organization needed, the duties of each man, the equipment and its placement, and the places where supplementary fire-fighting labor, equipment, and transportation can be obtained. The plan should include an outline map—the best available—upon which are shown such things as transportation and communication routes; habitations, logging operations, and other hazards; green timber that might act as a firebreak; and water, including prospective fire-pump settings. Figure 16 is a sample fire-plan map. The plan should outline the strategy that ought to be employed, assuming fires starting on various parts of the area. The intensity of protection provided by the plan must of course be based upon a rather thorough rating of the fuels, of the rate of spread and the difficulty of control, and of the causative agencies. The plan should be revised annually.

DETECTION

All the logged-off lands within the protective unit, because of their high hazard, should be visible to a lookout not more than 8 miles distant. Lookouts should be employed during the entire period of fire danger, for 24 hours a day duty. Patrolmen will ordinarily

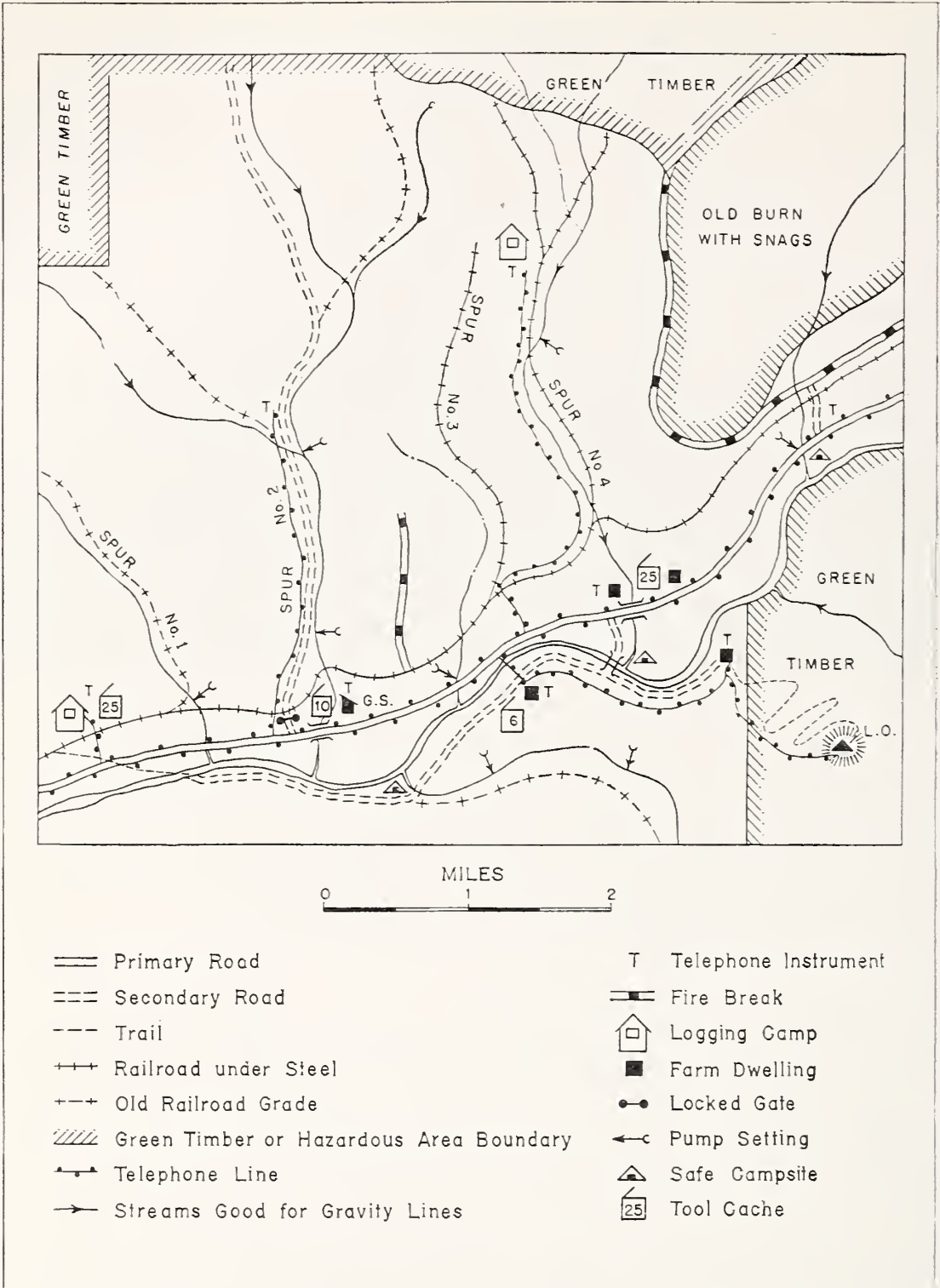


FIGURE 16.—A sample fire-plan map for a tract of logged-off land.

supplement the lookouts, especially along routes of heavy public use. Each lookout should be equipped with a fire finder (22) and a telephone that connects him with headquarters, where someone is constantly in attendance.

FIREMEN AND PATROLMEN

Sufficient firemen and patrolmen for the tract should be provided for the entire season. Ample provision should be made for early and late periods; some of the most disastrous fires on cut-overs have occurred outside the normal fire season. Firemen's and patrolmen's

duties will vary with the tract; always a warden or assistant should be at a nearby headquarters on the phone. If roads traverse the area, auto patrol in a truck equipped with tools, pump, and a small tank is very desirable. If the public makes much use of the tract, patrol of trails and fishing streams is also desirable. In addition to pumps, hose, trucks, plows, tractors, etc., there should be plenty of hand tools and back-pack pumps on hand at strategic places.

TRANSPORTATION AND COMMUNICATION

Logged-off land is often traversed by a network of abandoned railroad grades and truck roads that can be opened and maintained for auto travel very easily. This should be done, but public use of these roads should be discouraged by gates. Telephone lines should be available so that patrolmen or improvement crews can call up headquarters frequently for instructions or talk direct with the lookouts.

PRESEASON PREPARATIONS

During the early part of the season, when the hazard is light, the protection force should devote its time to opening up trails, roads, and telephone lines, putting tools in shape, and getting everything ready for the efficient working of the protection plan. Systematic training should be given to lookouts, patrolmen, and firemen. Educational work should be done with local communities and individuals to make them careful with fire.

It is assumed that all snags have been felled at the time of logging; if not, just as much of this work as possible should be done. Cleaning up the inflammable debris around campgrounds and along roads and streams used by the public is another desirable hazard-reduction measure.

FIRE-DANGER RATING

It is very desirable that the fire warden at headquarters make a daily rating of the fire danger (18) taking account of fuel moisture content, relative humidity, wind velocity, herbaceous stage, visibility, and causative hazard. He can thus better direct his men and vary the size of the protective force to meet each situation. He should avail himself of the fire-weather forecasts of the Weather Bureau in making these ratings and in planning his day-by-day protection activities.

PRECAUTIONS IN NEARBY LOGGING OPERATIONS

Logging operations, both through the summer and during the slash-burning season, carry a great threat of fire to contiguous logged-off land. It is, therefore, an important phase of protecting the reforesting land, recognized in the law and by all careful operators, to make sure that every possible precaution is taken on the operation, including shut-downs during hazardous weather.

EXCLUSION OF THE PUBLIC

The general public assumes the privilege of going upon private logged-off lands for fishing, blackberrying, hiking, etc., as though it

were common property, with the result that a large percentage of fires that start on these lands is caused by their campfires and cigarettes. Indiscriminate public use of these highly inflammable areas during the summer is incompatible with effective fire prevention. It is strongly recommended that private logged-off lands be closed to the public during the critical fire season, as are some of those on the national forests and as is the Tillamook burn and formerly was the Olympic blow-down. People can be kept out of some areas with very little patrol; from other areas exclusion is difficult. A system of registering those who want to traverse the area by trail or private roads might be employed in lieu of complete exclusion. Some resentment on the part of people who have been used to making free use of these areas may be expected at the outset, but they will get used to the restrictions as they have to other taboos.

SUPPRESSION OF FIRES

Speed is the essence of success in combating fires on logged-off land—speed in detection, communication, getaway, transportation, and fire fighting itself. The rule should be to hit fires hard at the start with as many men as is reasonable; it will save expense later. Direct attack should be employed wherever possible, in preference to letting the fire run over once-burned land to a natural barrier, possibly ruining reproduction on the intervening acreage. Backfiring should be done only when necessary and then in such a way that the least possible area is burned over. Water is the most effective enemy of fire and ought to be employed to the fullest extent possible. Tractors with plows can be used for fire-line construction on many logged-off areas and are very effective.

Fire fighting should be unremitting until the blaze is corralled; then mop-up and intensive working patrol should follow until the area is safe—usually when the last spark is out, and this generally means only after much rain or surface water has been poured on the area.

INCIDENTAL COMMERCIAL USES OF CUT-OVER LAND

Logged-off areas have certain resources that can be commercialized in the first two or three decades after cutting, before the new stand is old enough for thinning, or for pole, tie, or pulpwood cuttings, and long before the forest crop of sawlogs is ready to harvest. Utilization should be consistent with the primary objective, timber growing. At best, it may bring in a revenue that will help materially toward the payment of taxes and protection charges. All these resources of logged areas should be dispensed on a permit basis, with appropriate charges. People should be severely discouraged from the practice—all too common now—of helping themselves to anything they want, from Christmas trees to cordwood, without reference to the landowner. If all owners agree on a firm policy of stopping trespass and enforcing a paid-permit system, as is now done on the national forests, it will not be long before the public complies. Owners of contiguous lands might well pool the administration of minor uses as a measure of efficiency and economy.

SALVAGE CUTTINGS FOR MINOR PRODUCTS

After the ordinary saw-timber operation, a great deal of usable material that cannot be handled economically by the procedure used for sawlogs is left behind. If the area is accessible to markets and is traversed by roads, sale of the rights to take out this material is possible; much is now gleaned by small operators. "Cedar" products are especially sought, such as shingle bolts and fence posts. Pulpwood and fuel wood can be cut in short lengths from undersized trees, cull logs, chunks, and tops, and stacked along truck roads and railroad grades, where this class of material could not profitably be handled by the large machinery used in the saw-timber logging. Maple, cottonwood, and alder that have been passed up by the softwood-timber logger may be worth enough to the dealer in these special products to justify salvaging. Such salvage cutting helps to remove inflammable material from the area, as well as to bring in revenue, and if care is taken to avoid damage to seedlings and to safeguard against fire it appears to have no disadvantages.

GRAZING

Logged-off land, particularly if the slash has been burned, produces considerable vegetation that is palatable to sheep, goats, and cattle, especially the first two. Where land is dedicated to timber growing, the sowing of grass seed is usually inadvisable because, if for no other reason, the forest cover will stop grazing use before the investment in seed and seeding has been recovered. The grazing of sheep (?) (and goats), by removing herbage that would otherwise become tinder, is temporarily beneficial. Continued grazing, however, is thought to induce growth of the unpalatable bracken at the expense of the more fire-retardant brush and low herbage. Damage to seedlings by browsing of sheep or cattle is not serious unless the range is overcrowded or the stock is allowed to concentrate. Goats are considered more destructive to tree growth. Trampling may cause damage during the period of seedling establishment, and, in steep country especially, sheep should not be allowed on reproducing areas for 2 or 3 years after slash burning. Cattle usually do not range widely enough over unseeded logged areas to utilize the forage thoroughly. Sheep are the preferred class of stock, but they should be handled by a herder. As the older logged areas acquire a cover of trees and shrubs, their suitability for grazing will disappear and the stock will progressively be moved to the more recent cut-overs. Grazing rentals should go a good way toward paying taxes for a few years.

BEE PASTURAGE

It is the practice of some beekeepers to move their hives in the summer onto logged-off areas to take advantage of the fireweed, vine maple, etc., which are prevalent and are excellent sources of honey. This is a very desirable use of logged areas, but it, too, ought to be on a permit basis with a small fee. This should be advantageous to the beekeeper, for thus he can get exclusive use of an area.

CASCARA-BARK PRODUCTION

Very commonly cascara trees are present on logged tracts. Trespass may develop unless a firm policy of requiring permits is enforced by all the major owners in a district. When the trees are large enough for profitable peeling, but not before, peeling rights should be sold under terms that guard against waste and conserve the species, or men might be hired to do the peeling on a piece-work basis. Giving one operator a definite territory will help to keep trespassers off, and one party can then be held responsible for results.

PRODUCTION OF CHRISTMAS TREES AND OTHER GREENERY

Ten to fifteen years after logging, areas in parts of the Douglas-fir region—especially where growth is not very rapid—produce saplings that are much in demand for Christmas trees. Repeated and unregulated cutting of these saplings is not consistent with good management for timber production, for the cutter inclines to take the best trees in the openings, and thus overcut the sparse stands rather than thin the overstocked stands. However, properly regulated cutting should minimize the harm and may easily bring in enough revenue to compensate for the taxes since the time of logging. The land manager should not issue Christmas-tree permits until the stand is fully old enough, should limit the number of trees to be cut per acre, or should specify that no tree should be cut unless there is another within a certain distance, should insist that the stumps be cut near the ground level, and should require that all of each tree cut be carried to central assembly points for sorting and disposal of the refuse.

Other forms of greenery for florists' use or holiday decoration, such as evergreen huckleberry, cedar boughs, ferns, and moss are in demand, although more often sought on uncut areas. Logged-off lands are also a commercial source of living plants, such as rhododendron, and of roots and bulbs. Such uses, however slight, should be handled by permit in order to discourage indiscriminate occupancy of logged-off areas. Fortunately most of these products are taken at a time of no fire danger.

BLACKBERRY PICKING

In June and July many people go blackberry picking and seek the most accessible logged-off areas. This use is undesirable from the point of view of the forest owner because it comes during the fire season and can rarely be expected to yield a revenue. Where the fire hazard is high it should either be prohibited altogether or, if such control is possible, placed on a permit basis by having pickers register with a fire warden at the point of entry to a logged-off tract.

ORGANIZATION FOR HARVESTING BYPRODUCTS

It would be highly desirable for the manager of a large tract of forest land to build up from among the small farmers of the lo-

cality a group upon whom he could depend to harvest the byproducts and perhaps also to act in season as fire wardens and guards to prevent trespass. These men, permanent residents on nearby agricultural lands or subsistence homesteads, might run grazing stock, cut fuel wood or fence posts, harvest Christmas trees and cascara bark, and pick blackberries for market. Thus the forest landowner would have working with him a coterie of dependable citizens who were jointly interested in the welfare of the forest property. Under such a system the number of persons using the area would be kept to a minimum, resulting in a reduction in fire hazard and trespass.

SUMMARY

The 3½ million acres of recently logged land and older non-reforestation cut-overs in the Douglas-fir region present difficult problems of protection and land management which are aggravated each year by 125,000 to 175,000 acres converted from virgin forests to bare cut-over land. This great acreage is now only partially fulfilling its potentiality for producing forest products of great economic importance, largely because protection and management of this land in the past have been inadequate. From 1926 to 1930, inclusive, 3.9 percent of the recently logged lands reburned annually. As a result of repeated fires and inadequate seed supply 71 percent of representative lands logged between 1920 and 1923 failed to reforest satisfactorily in 10 years.

Since the objective of the management of lands chiefly valuable for forest products is to obtain a fully stocked stand of desirable forest trees in the shortest possible time at the least cost, stable ownership and a serious intent to carry out a long-term policy for the continuous production of forest crops are essential. To attain this objective, essential measures must be taken to provide an adequate seed supply and to safeguard the area from all fires.

Security from fire is the all-important prerequisite for timber growing on these cut-overs. Maximum security is attained only with the restoration of a continuous cover and this is usually not until the second-growth trees are 25 or more years old. Prompt and dense reforestation on cut-over land is the best means of making such land safe from fire and keeping down fire-protection costs. Prevention of accidental fires is attained in two ways, usually in combination, namely, direct prevention by employing partolmen, various precautionary measures, etc., and hazard reduction through felling of snags, burning of slash, etc.

Because of the present standards of utilization there is an enormous quantity of debris on the ground following clear-cutting, which under present standards of fire prevention and control constitutes a very serious fire hazard. Disposal of the slash is highly desirable as a fire-protection measure. Broadcast burning of extensive slashings is the only practicable method of disposal under present conditions, but it is effective in reducing hazard only when it consumes a high percentage of the fine fuels yet does not add to the hazard by killing standing trees.

Broadcast burning has only one real advantage—the removal of some of the fire hazard, thus facilitating subsequent fire control and re-

ducing the chance of disaster from an uncontrollable fire. This advantage is very important, though temporary in effect, and under present conditions generally outweighs all the disadvantages.

Broadcast burning has several disadvantages. It lessens the changes for quick or adequate natural reforestation. It usually kills all the advance reproduction, some potential seed trees, and often some adjoining merchantable timber. It may impair the physical or chemical condition of the soil. It increases the chances for soil erosion and rapid run-off in steep country. It is unfavorable from a recreational and aesthetic viewpoint.

The effects of slash burning upon insect infestations, grazing use, and game management, in comparison with no burning, are inconsequential so far as known.

The degree of hazard reduction effected by burning depends upon many local conditions. Each area is a problem in itself; blanket rules will not apply. Each operator should carefully study his tract, estimate the type of burn he is likely to get, appraise the probable hazard reduction through a term of years (both in rate of spread and resistance to control), and then decide whether the advantages of burning will offset the disadvantages. The rate-of-spread factor is immediately reduced by slash burning, but the vegetation builds it up again rapidly until it is about the same on burned as on unburned areas in approximately 6 years. The resistance-to-control factor is less on burned areas for many years. The combination of these two factors into a hazard rating indicates that, whereas immediately after slash burning unburned areas are about 18 times as hazardous as burned areas (expressed in terms of the relative amount of effort required to control fires on unburned and burned areas, and assuming equal inception danger on both), about 20 years after cutting the hazard is equalized on both areas. The aggregate amount of hazard during two decades is in the ratio 1.6 for unburned areas to 1.0 for burned areas.

The advantages and disadvantages of burning a cut-over tract should be considered from the long-term viewpoint. Too often the condition of the land immediately after burning is used as a criterion of success; rather its probable aggregate condition over a term of 10 or 20 years should be used as a measure of the desirability of burning or not burning the slash.

This study indicates, however, that until the public is more fire-conscious and until there is more economic incentive to expend much more money on the protection of unburned slash areas, it will probably be wise and necessary to continue to broadcast burn most of the clear-cut slash in the Douglas-fir region. However, the forest manager who is interested in obtaining the maximum continuous production of forest products from his land may find that in certain combinations of topography, climate, and forest type, or where fire-causative agencies are few, it will pay him to leave some areas unburned, particularly those that are isolated or are not too continuous without a firebreak.

The following principles are suggested as guides for those who decide whether or not to burn. Slashings should be burned:

1. Where the chances of accidental fires are high or the opportunities for fire control are poor.

2. Where the cutting is clean and there is not an understory that would be killed by the fire and make another hazard comparable to the initial slash.

3. Where the conflagration hazard is high, due to very extensive areas of recent cuttings.

Do not burn slashings:

1. Where a considerable reserve stand or understory would be killed by fire, thus making little or no net gain in reducing the fire hazard.

2. Where the logged-off area is well isolated from risk of fire and is not a particularly high hazard in itself.

3. Where a good stand of advance or subsequent reproduction promises to give shade and reduce fuel inflammability in a very few years.

In the spruce-hemlock belt of the coastal region, because of the less acute fire weather, more rapid disintegration of the flashy fuels of spruce and hemlock than of Douglas-fir, and quicker covering-up of the slash with fire-retardant vegetation, slashings which farther inland would be dangerous can be left unburned.

The following principles should govern the conduct of burning:

1. Burn promptly after logging.

2. Burn in the fall, unless prepared to mop up thoroughly after a spring burn. In the fall, burn after the first early rain, except in the wettest parts of the region, and always when it is not windy and just prior to a predicted rain.

3. Choose the day and the time of day when the backfires can be controlled, yet the slash will burn thoroughly without too intense burning of soil humus, seed in the ground, and reserved trees.

4. Confine the fire to the slash area, keeping it out of uncut timber and seed groups.

To achieve good slash burning the logging should be planned with that operation in view; machinery and down timber should be removed in time to burn each unit that should be burned. Advance preparation for slash burning should include the felling of snags, clearing out around bridges and camps, having a written plan of action, the construction of fire lines where needed, and having in readiness a crew of men with pumps, tank cars, hose, hand tools, etc.

The weather forecast should be consulted to assist in choosing the right day and hour to start the fires. Late afternoon or evening is preferred. The igniting should be done rapidly with due consideration for winds and topography. After the fire has covered the whole area, unless heavy rains ensue at once, the tract should be patrolled for spot and hang-over fires and mopped up until the last spark is out.

Slash burning does not end the fire hazard; it merely lessens it for a few years, and often creates falsely a feeling of security. In a few years slash-burned areas are as inflammable as unburned areas—though fires thereon are easier to control. Therefore, very intensive protection is necessary, on both burned and unburned logged-off land, until a forest canopy is reestablished. This requires a larger expenditure per acre than for a forested tract. On logged-off land there should be an especially well-manned, well-directed, and well-equipped organization for prevention, detection, and suppression of all fires. Since practically all fires on cut-over lands are man-caused, preventing the starting of fires is of major importance in keeping to a minimum the cost of control and the acreage burned. Fires that might be started by industrial activities or by the public must be prevented. Trespassing by the public on logged-off areas should be discouraged. A staff of wardens should be employed for each extensive contiguous

tract to prevent trespass, to issue permits, and to superintend uses of the resources, as well as to conduct fire prevention and control.

Planting of logged-off lands should not be necessary if a natural seed supply is provided and fire is controlled, and it is recommended only where natural regeneration is improbable, where reforestation must be speeded up, where there is a good chance that the area is safe from subsequent fires, and where the cost of planting can be justified for recreational, aesthetic, soil-conservation, or water-protection reasons.

Temporary grazing of logged-off land is not incompatible with timber growing, and may have some temporary beneficial effect on lessening the fire hazard by the consumption of the palatable vegetation. Other incidental uses of logged-off land such as cordwood-, shinglebolt-, and post-wood-salvage cutting, cascara-bark peeling, or Christmastree cutting, are to be encouraged as a means of producing a small early revenue, but only under formal permit.

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